RAFT
Radar Fence Transponder
Preliminary Design Review
19 Nov04

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MIDN 1/C JoEllen Rose

OLAW RAFT Team

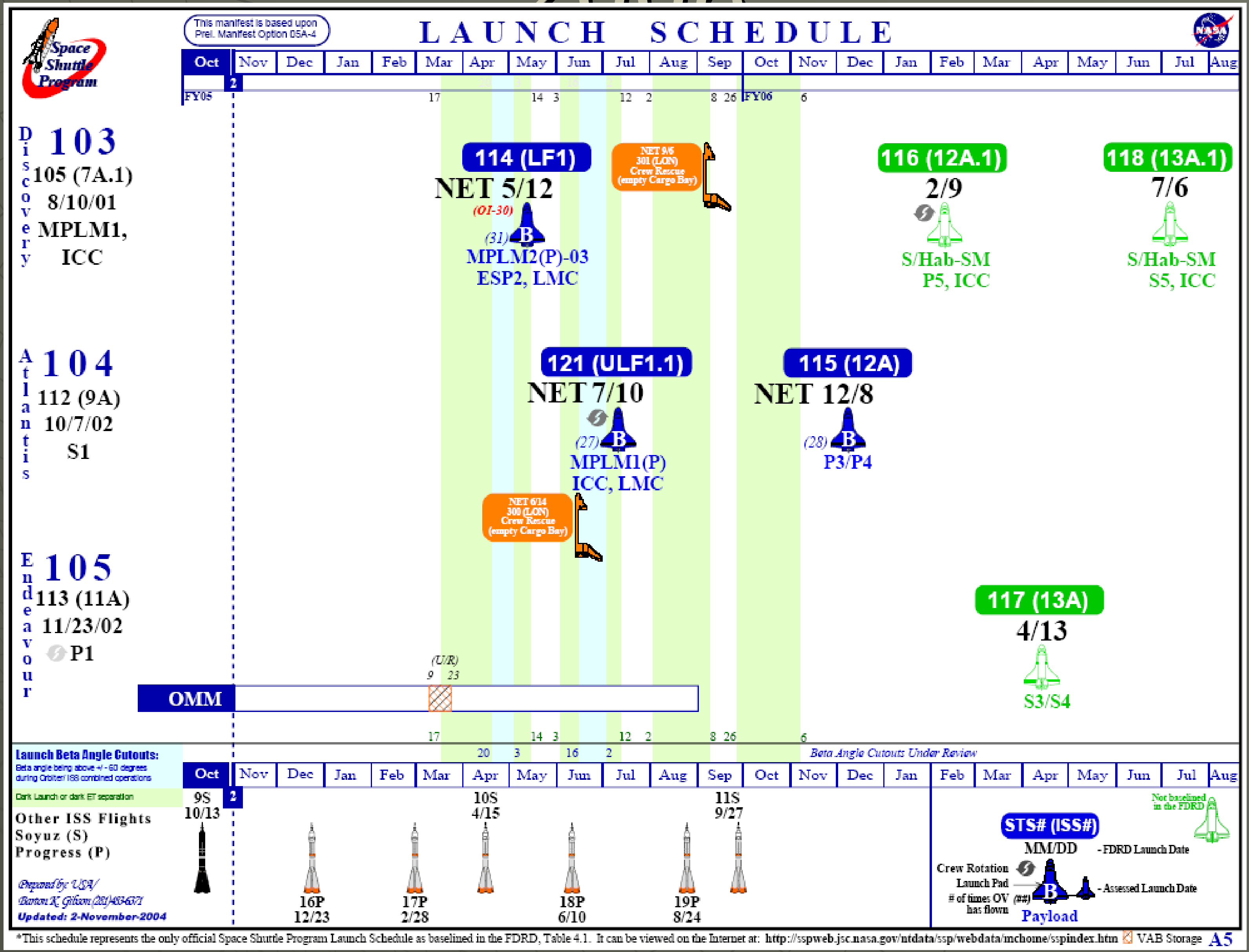
- Chief Of Integration & Ops: Capt Yvonne Fedee
- Payload Manager: Mr Perry Ballard
- Back Up Payload Manager: Lt Reann Caldwell
- Payload Integration Engineer(PIE): Mr Carson Taylor
- Launcher & Back Up PIE: Mr Scott Ritterhouse
- Safety Engineer (SE): Ms. Theresa Shaffer
- Launcher & Back up SE: Mr Darren Bromwell

Key Milestones: Tentative Schedule

- Assumption: Launch NET December 2005

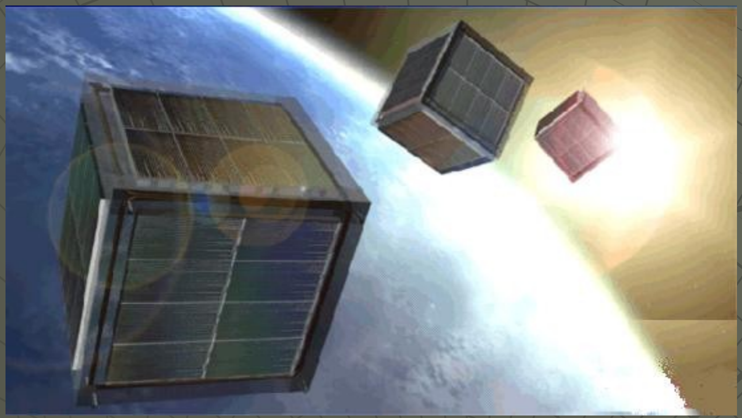
RAFT Kickoff		Apr 04
RAFT USNA SRR		Sep 04
RAFT PDR		**19 Nov 04**
Launcher CDR		Nov 04
RAFT Phase 0/1 Safety		Dec 04
RAFT CDR		Feb 05
RAFT Phase 2 Safety		Feb 05
RAFT Flight Unit Delivery		May 05
RAFT Phase 3 Safety		Aug 05
RAFT Delivery/Install		Oct 05
RAFT Flight (STS-116)	NET	Feb 06

Shuttle Manifest: 2004 - 2008



Background

30 to 50 in Construction



AIAA/USU Small Sat Conference

30% of papers were for PICO, NANO and CUBEsats

All

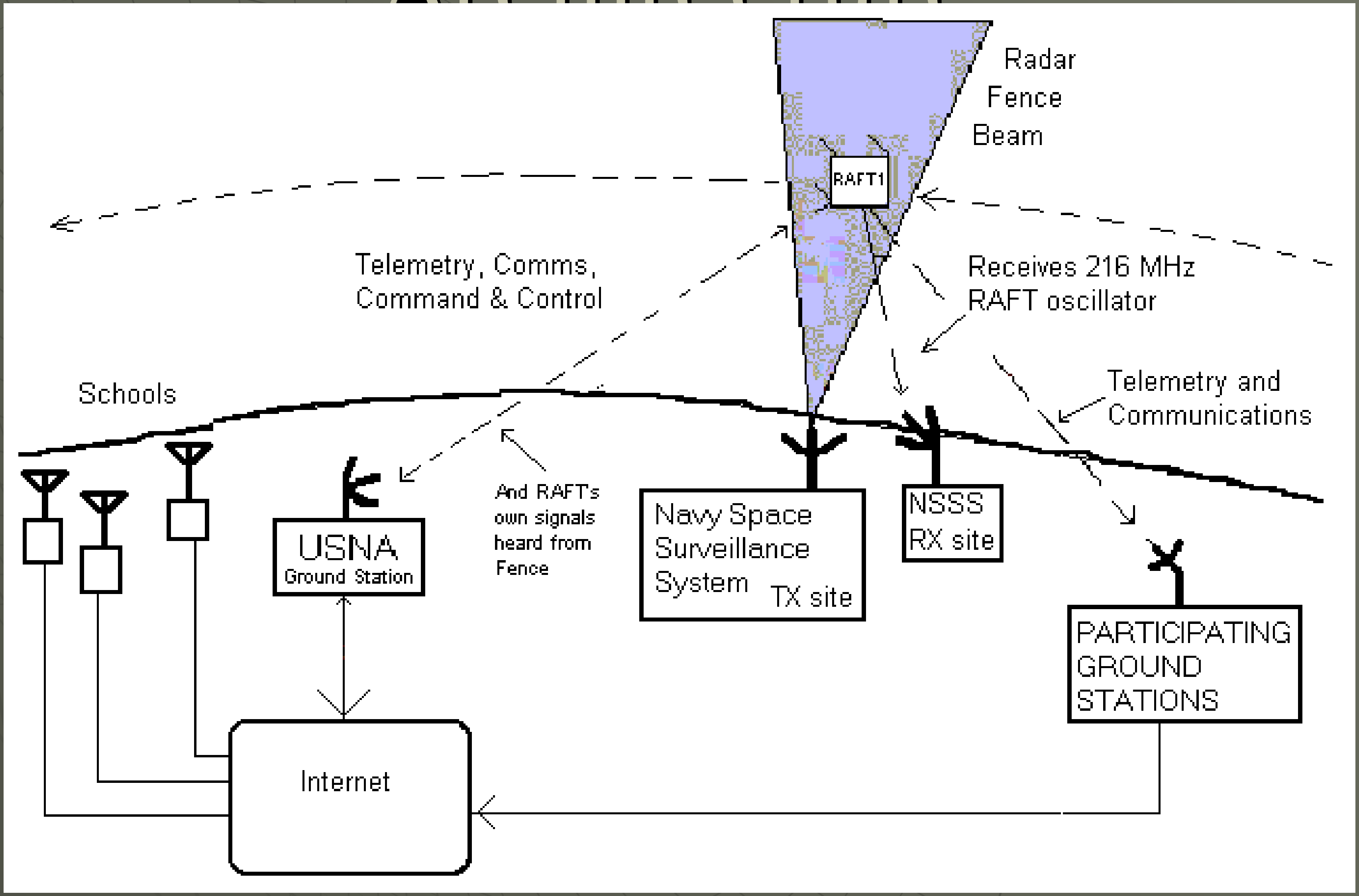
How to Track them???

Mission Statement

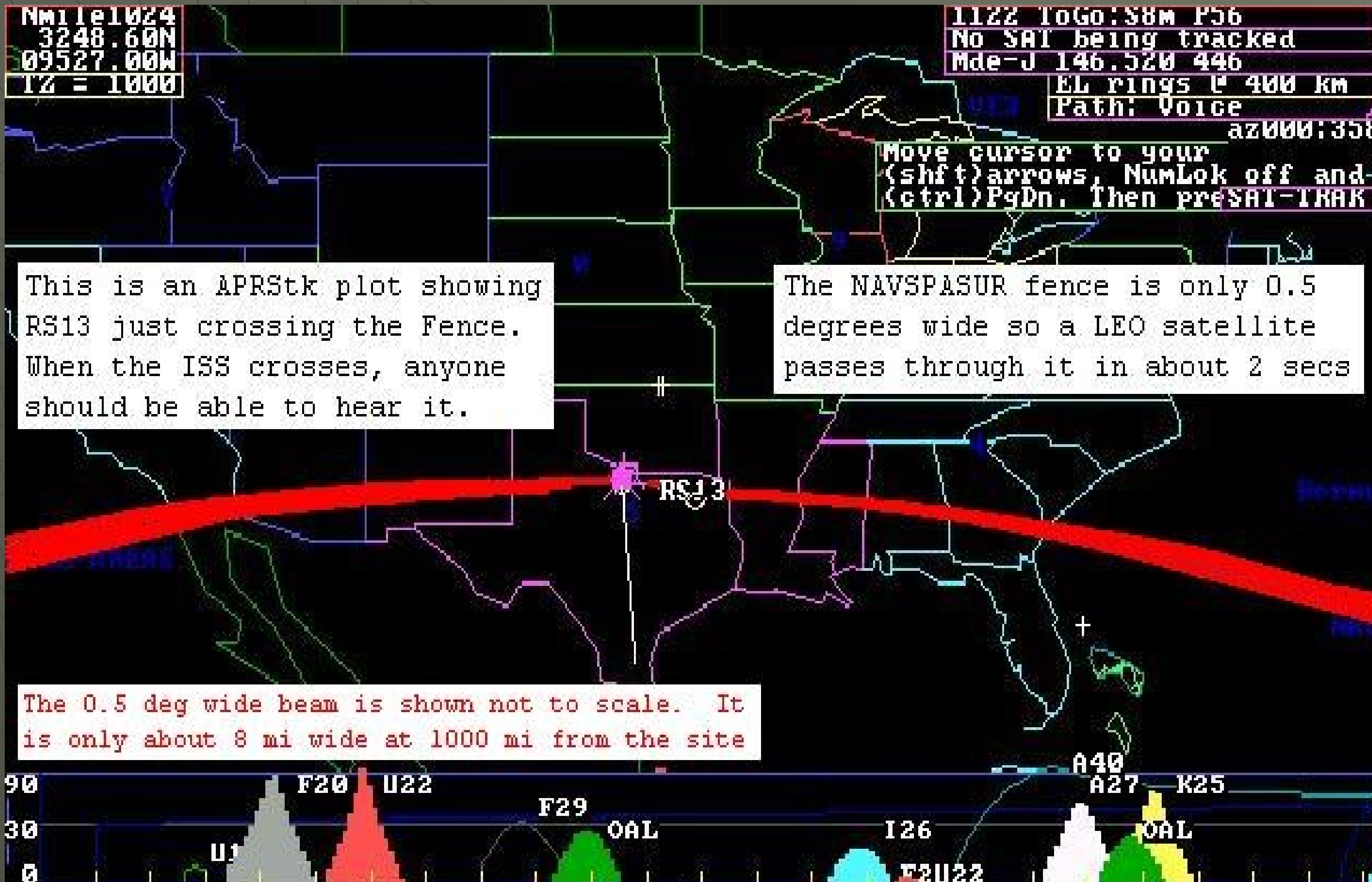
The mission of RAFT is:

- To provide the Navy Space Surveillance (NSSS) radar fence with a means to determine the bounds of a constellation of PicoSats otherwise undetectable by the radar fence
- To enable NSSS to independently calibrate their transmit and receive beams using signals from RAFT.
- This must be accomplished with two PicoSats, one that will actively transmit and receive, and one with a passively augmented radar cross-section.
- Additionally, RAFT will provide experimental communications transponders for the Navy Military Affiliate Radio System, the United States Naval Academy's Yard Patrol crafts, and the Amateur Satellite Service.

RAFT1 Mission Architecture



NSSS Radar Fence



NSSS Radar Fence

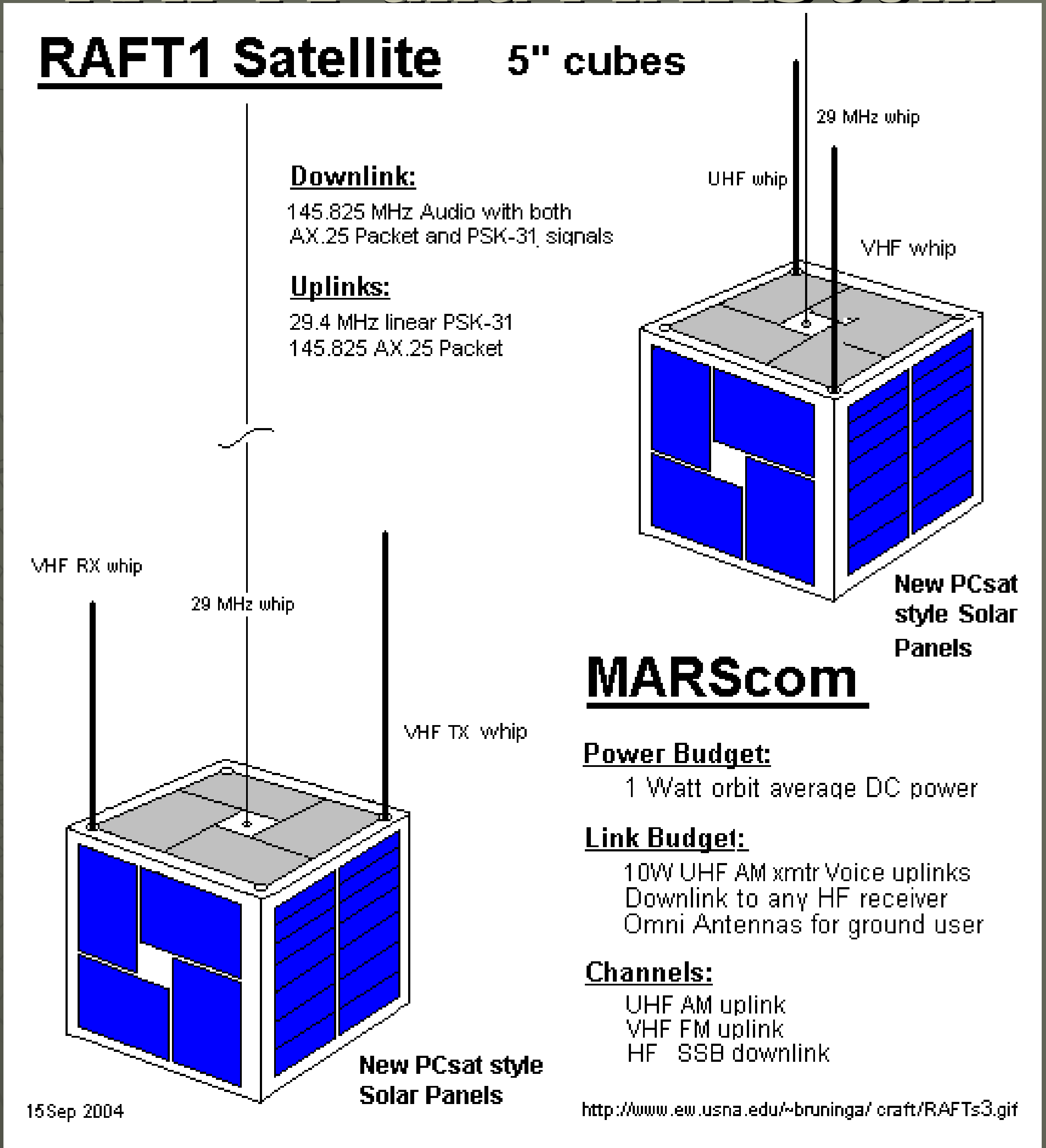
Transmit Power: 768 kW of power from Lake Kickapoo, TX

Antenna Gain: About 30dB

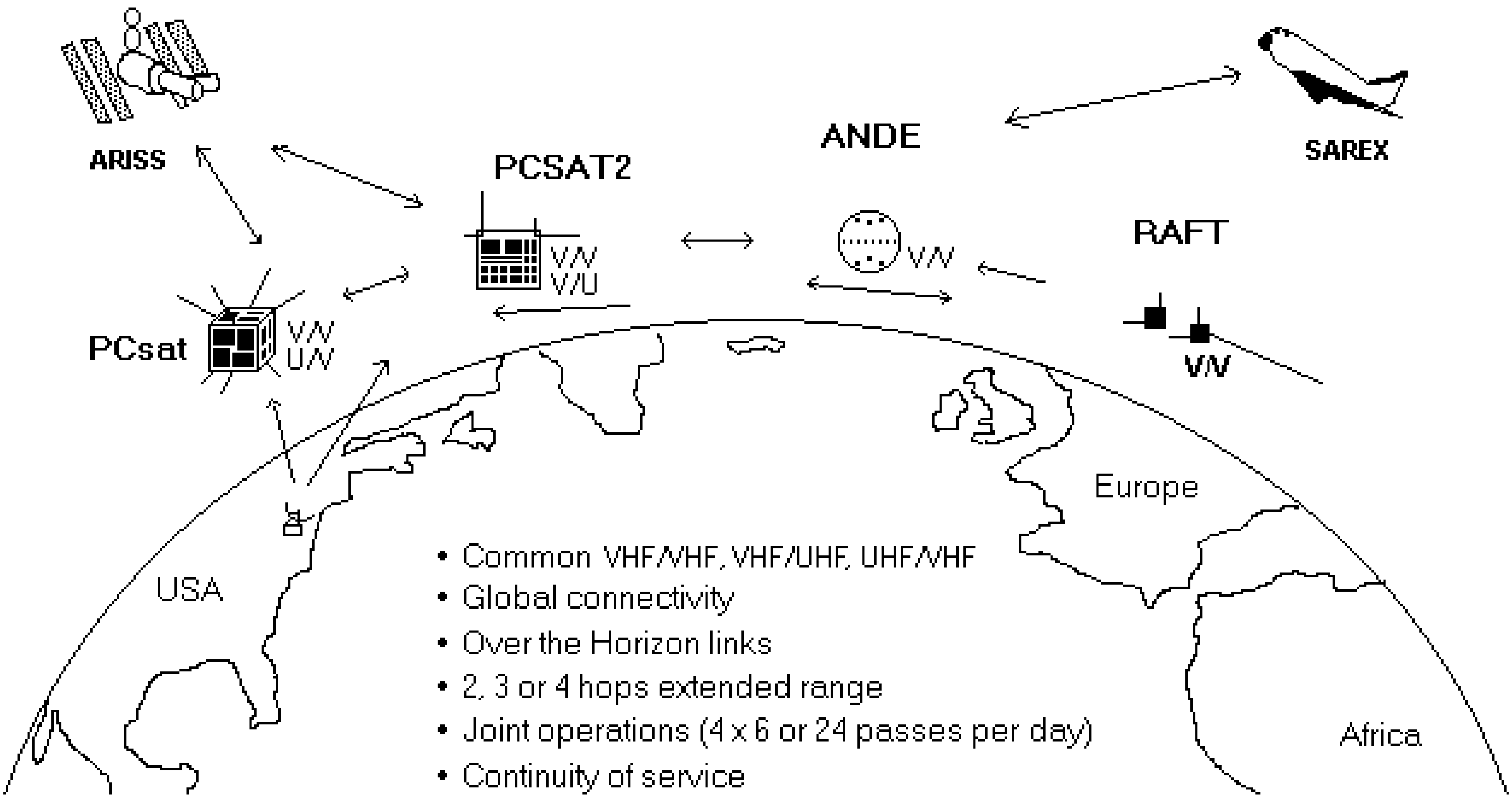
Transmission Sites: Lake Kickapoo, Texas
Jordan Lake, Alabama
Gila River, Arizona

Receiving Sites: San Diego, California
Elephant Butte, New Mexico
Red River, Arkansas
Silver Lake, Mississippi
Hawkinsville, Georgia
Tattnall, Georgia

RAFT1 and MARScom



Constellation Operation of USNA Satellites

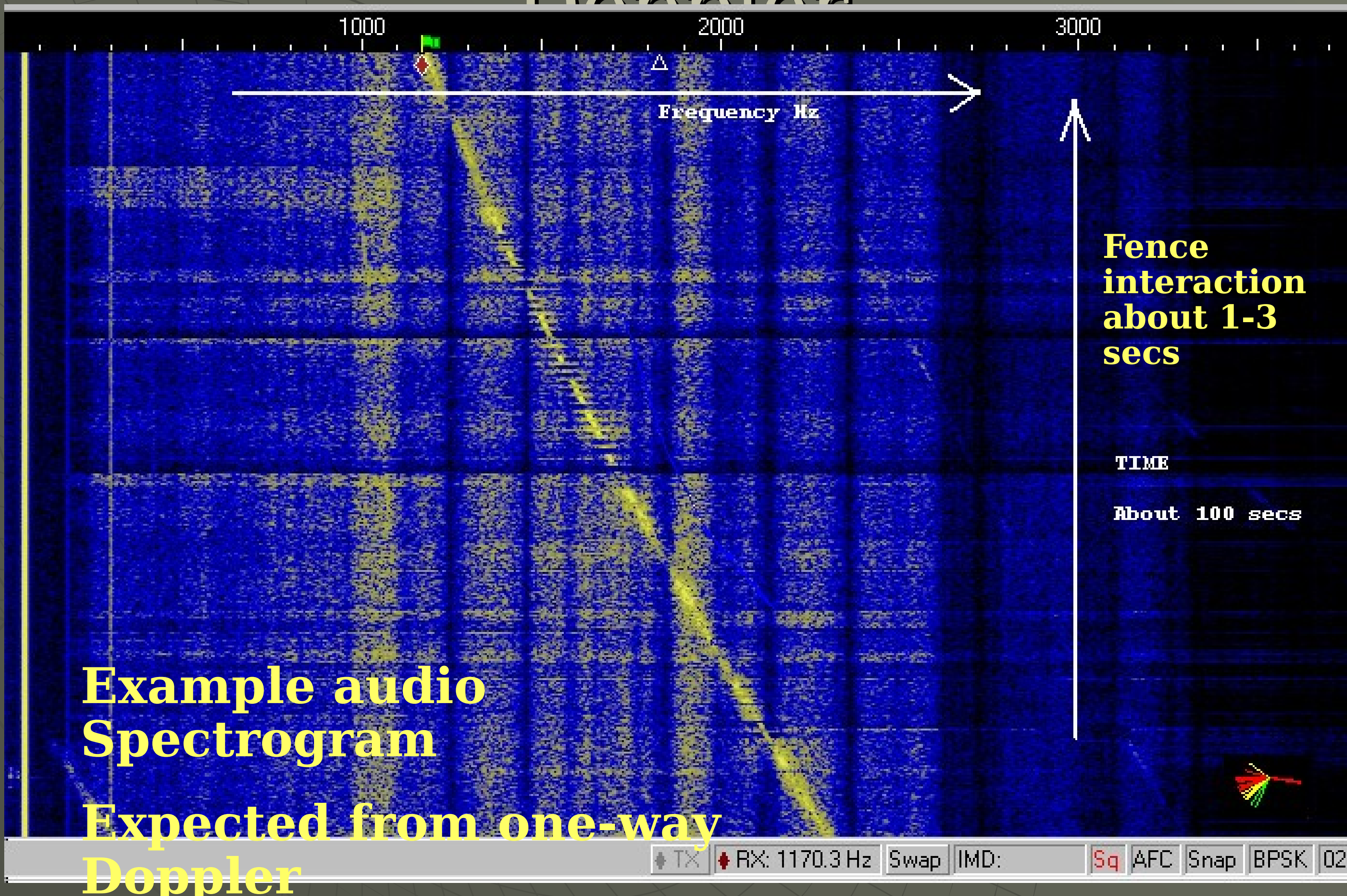


- Common VHF/VHF, VHF/UHF, UHF/VHF
- Global connectivity
- Over the Horizon links
- 2, 3 or 4 hops extended range
- Joint operations (4 x 6 or 24 passes per day)
- Continuity of service

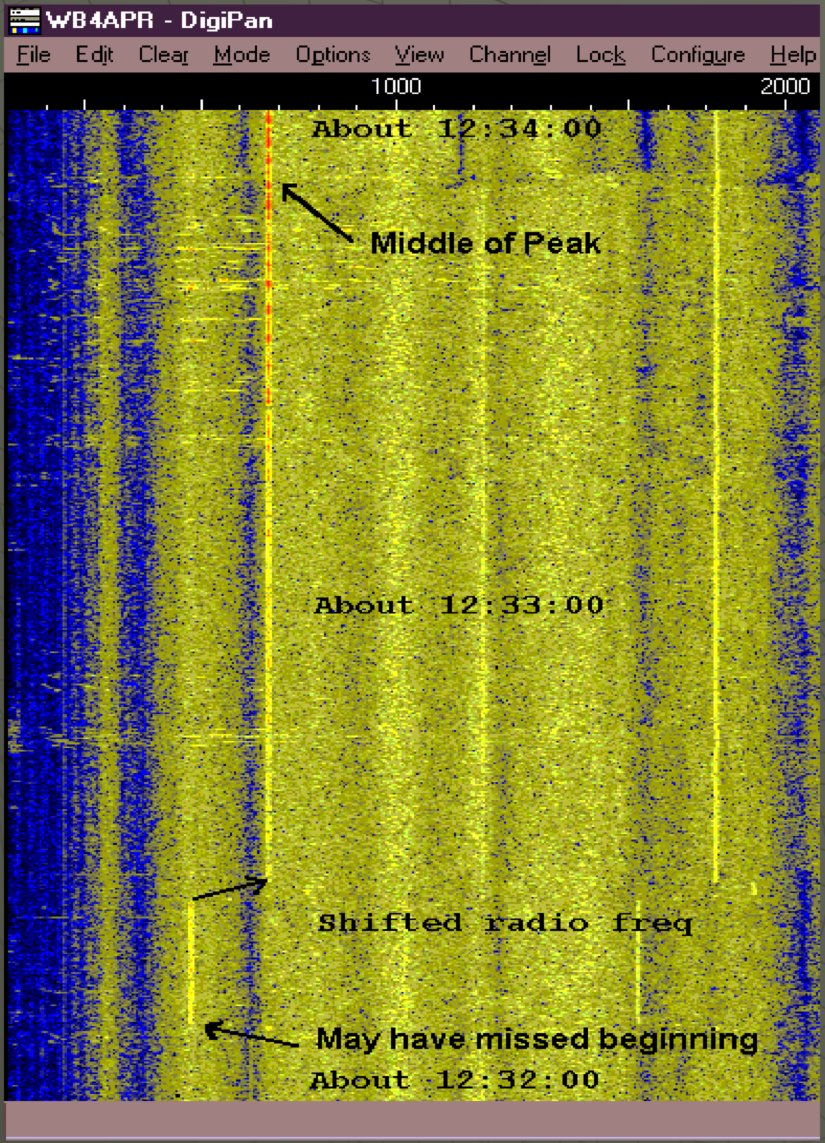
WB4APR

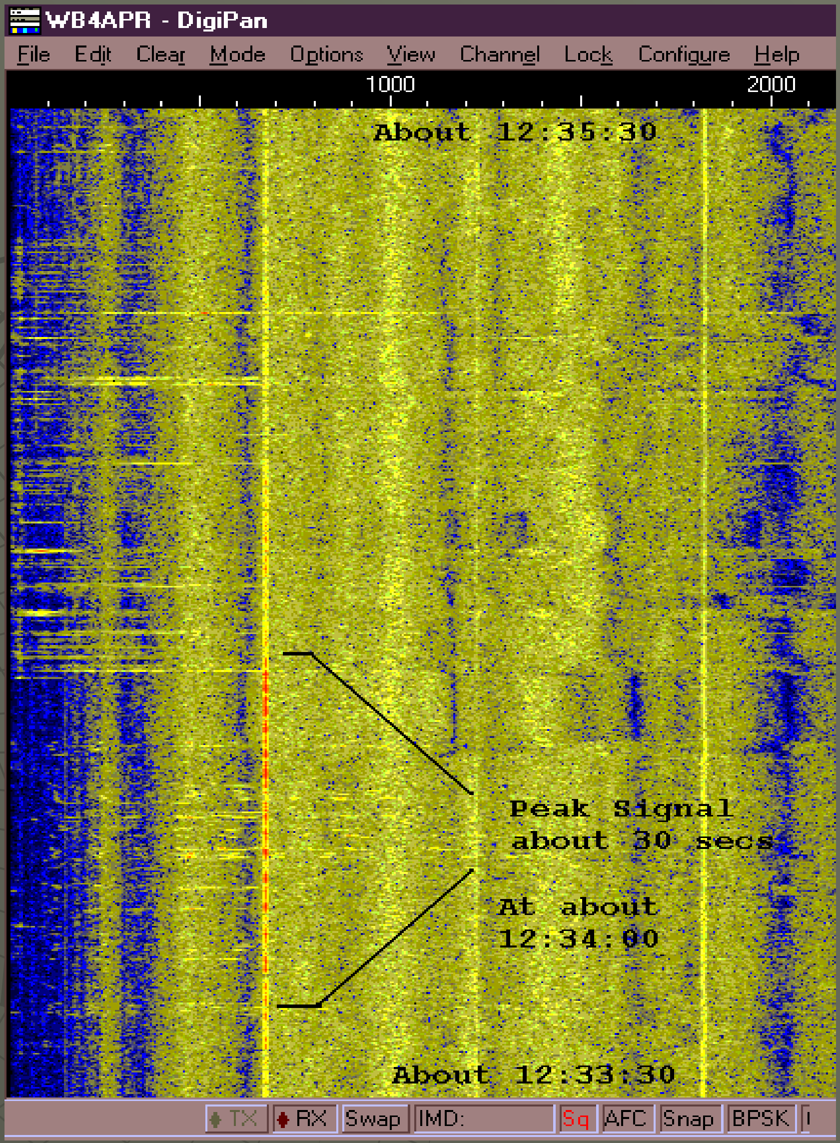
http://www.ew.usna.edu/~bruninga/craft /USNAsats.gif

Spectrogram of Satellite Doppler

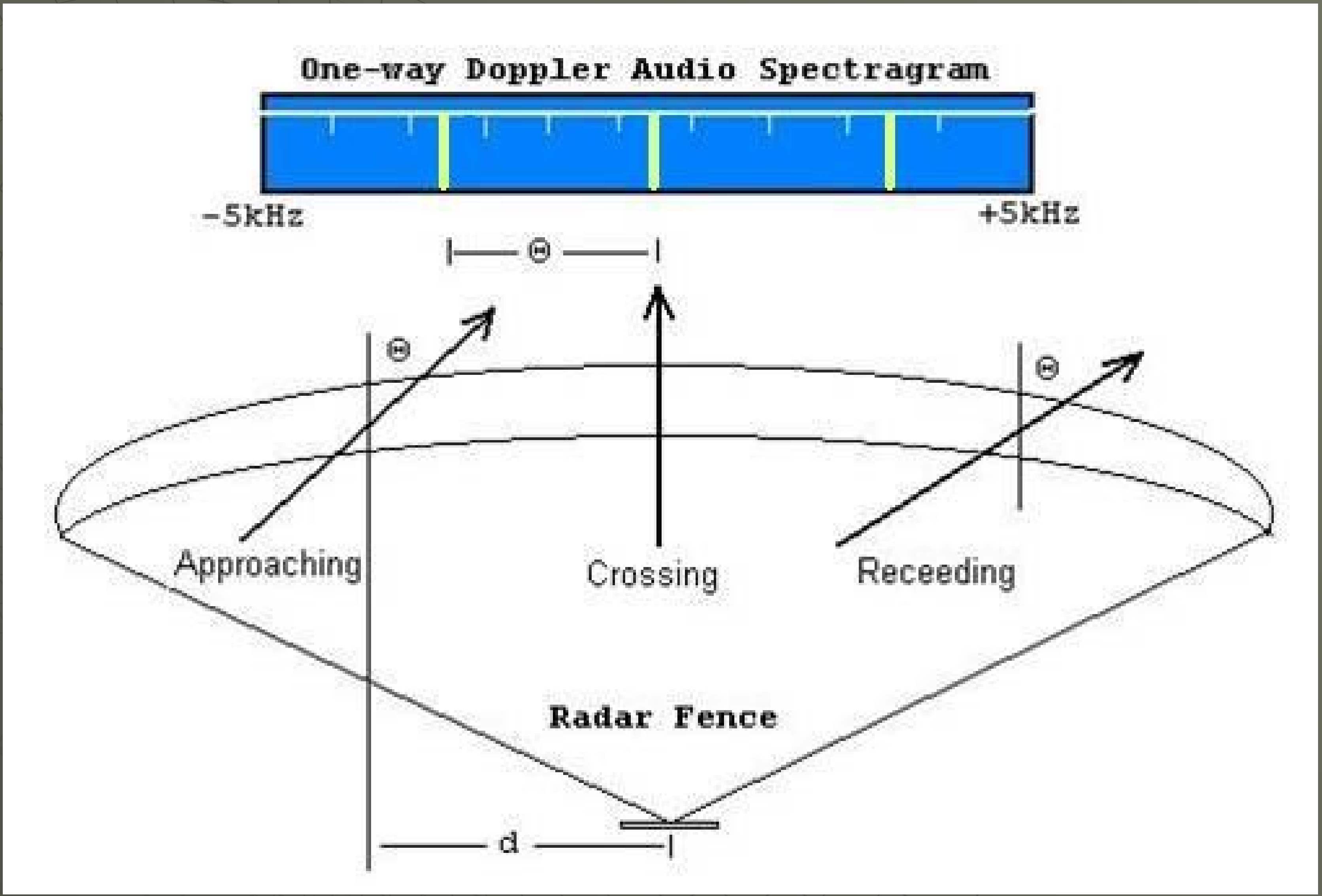


NSSS / Moon Intercept

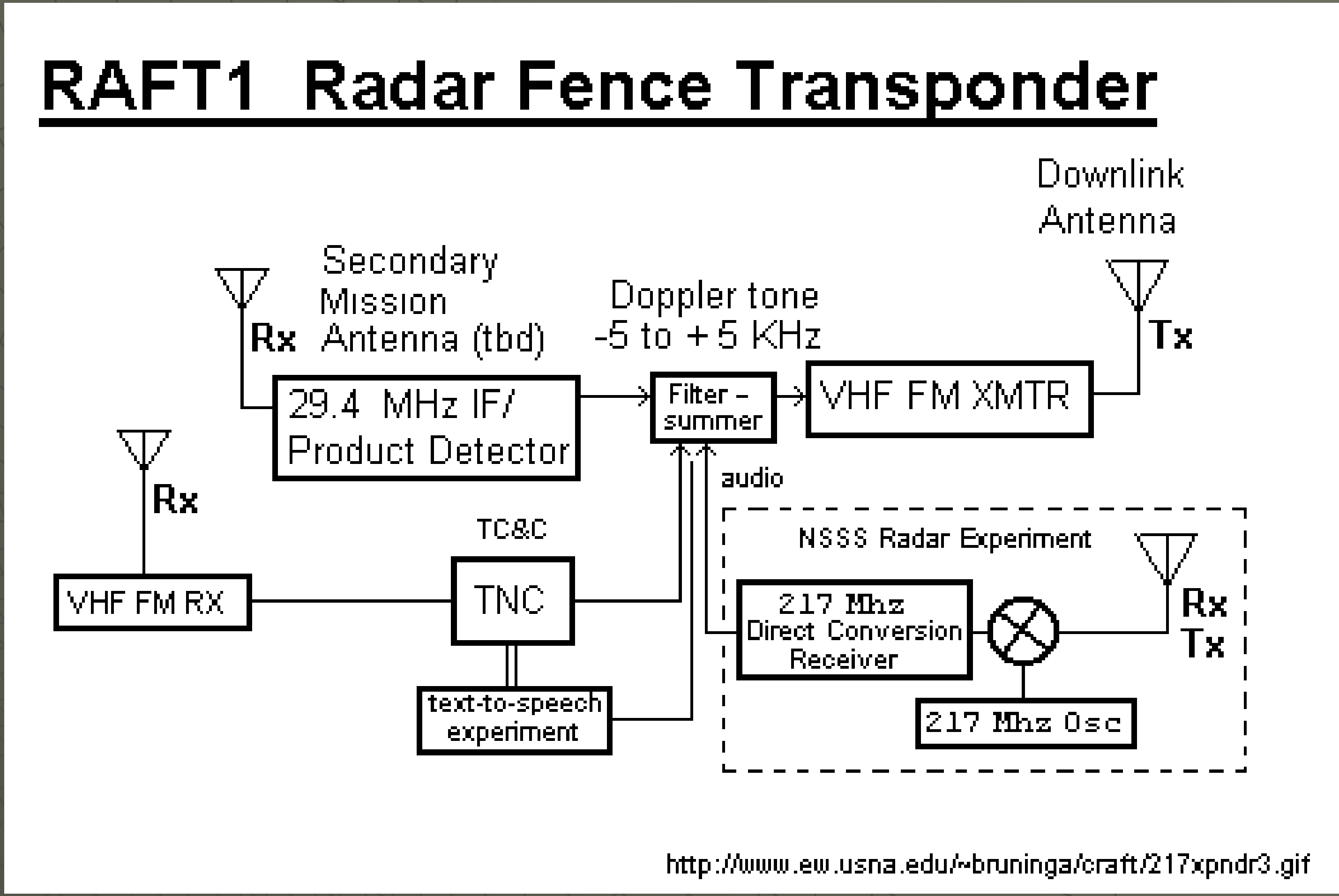




Pass Geometry

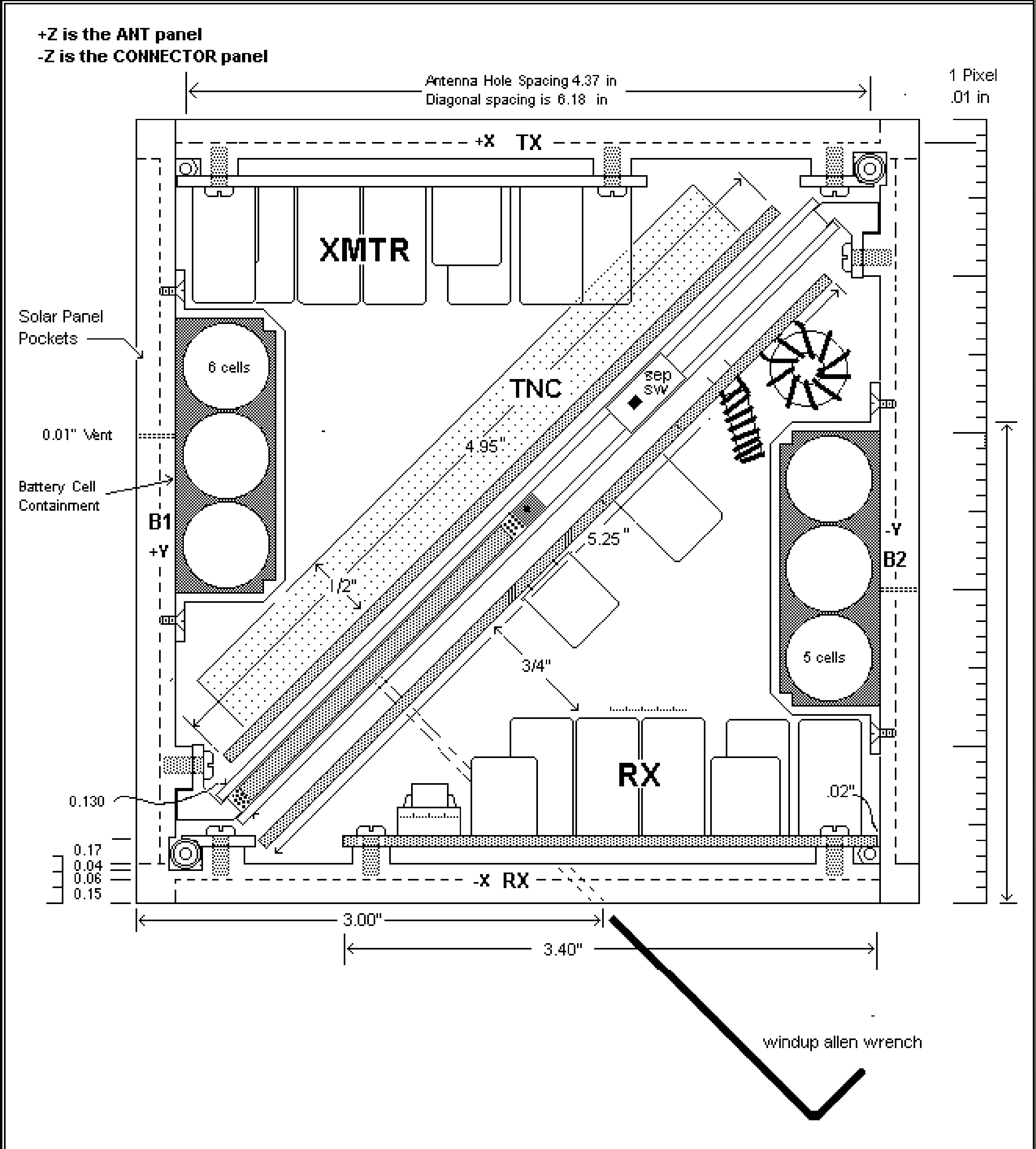


Raft1 Block Diagram



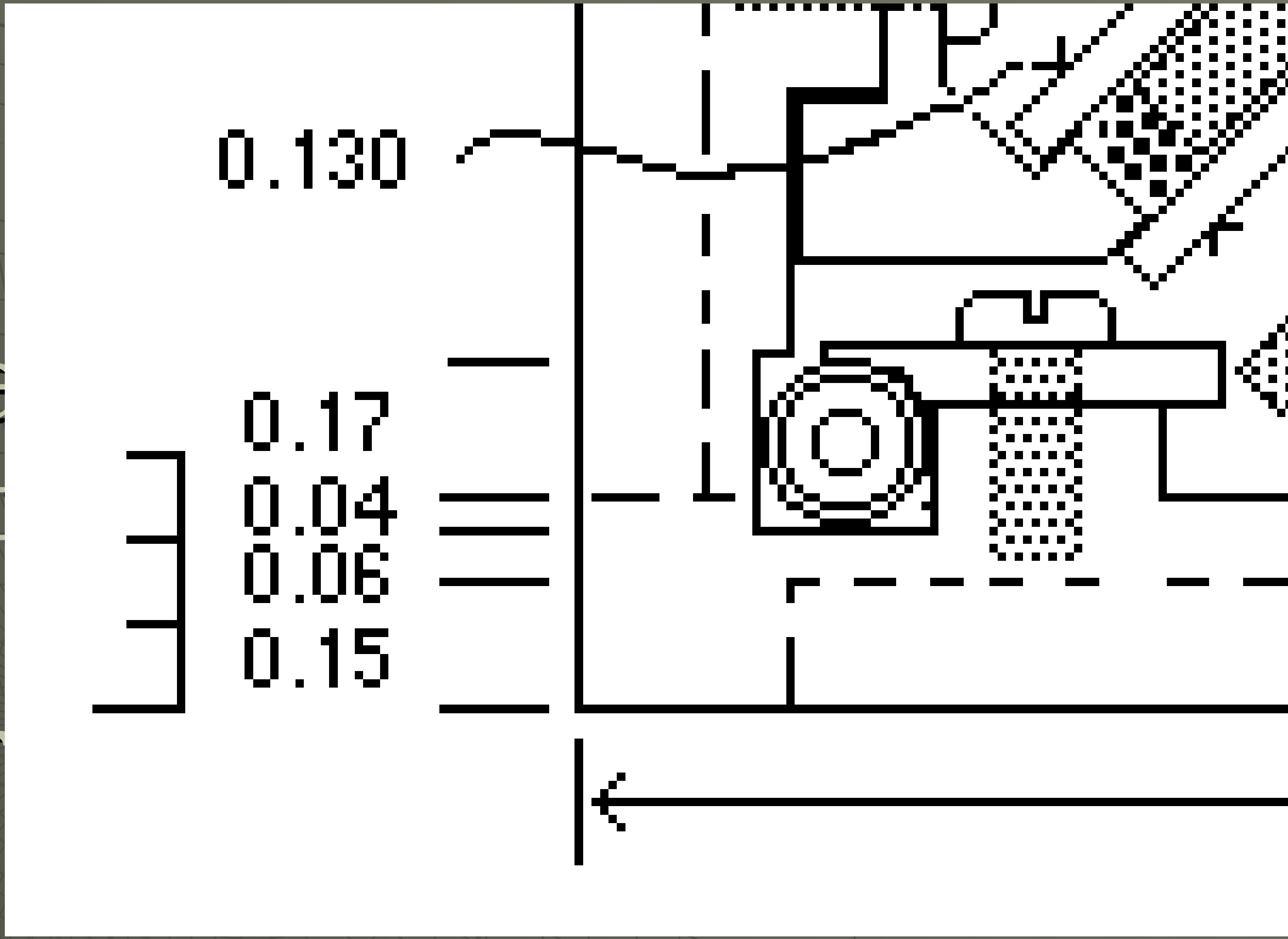
RAFT1 Internal Diagram

Top View

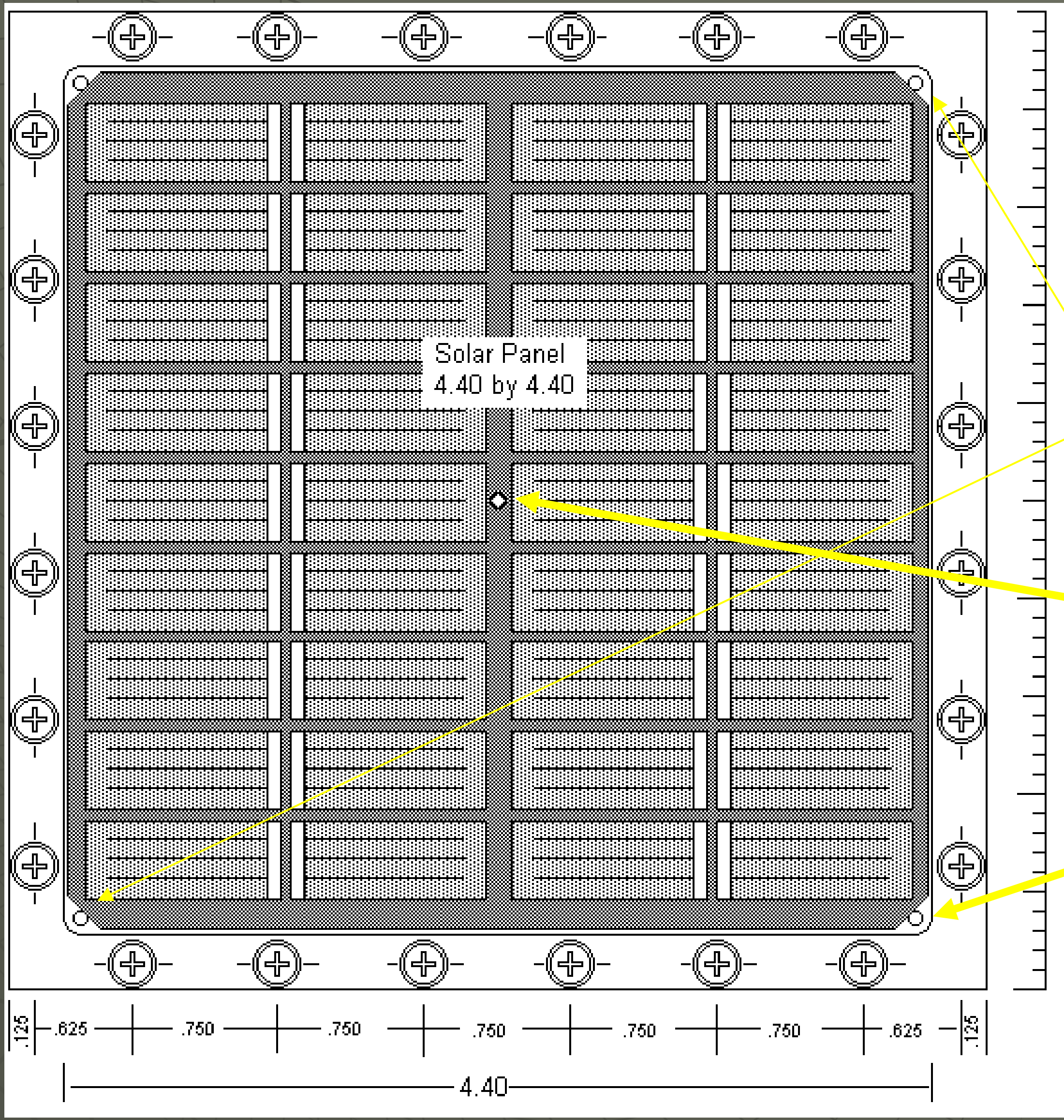


RAFT Internal Diagram

Corner Detail



Top Panel

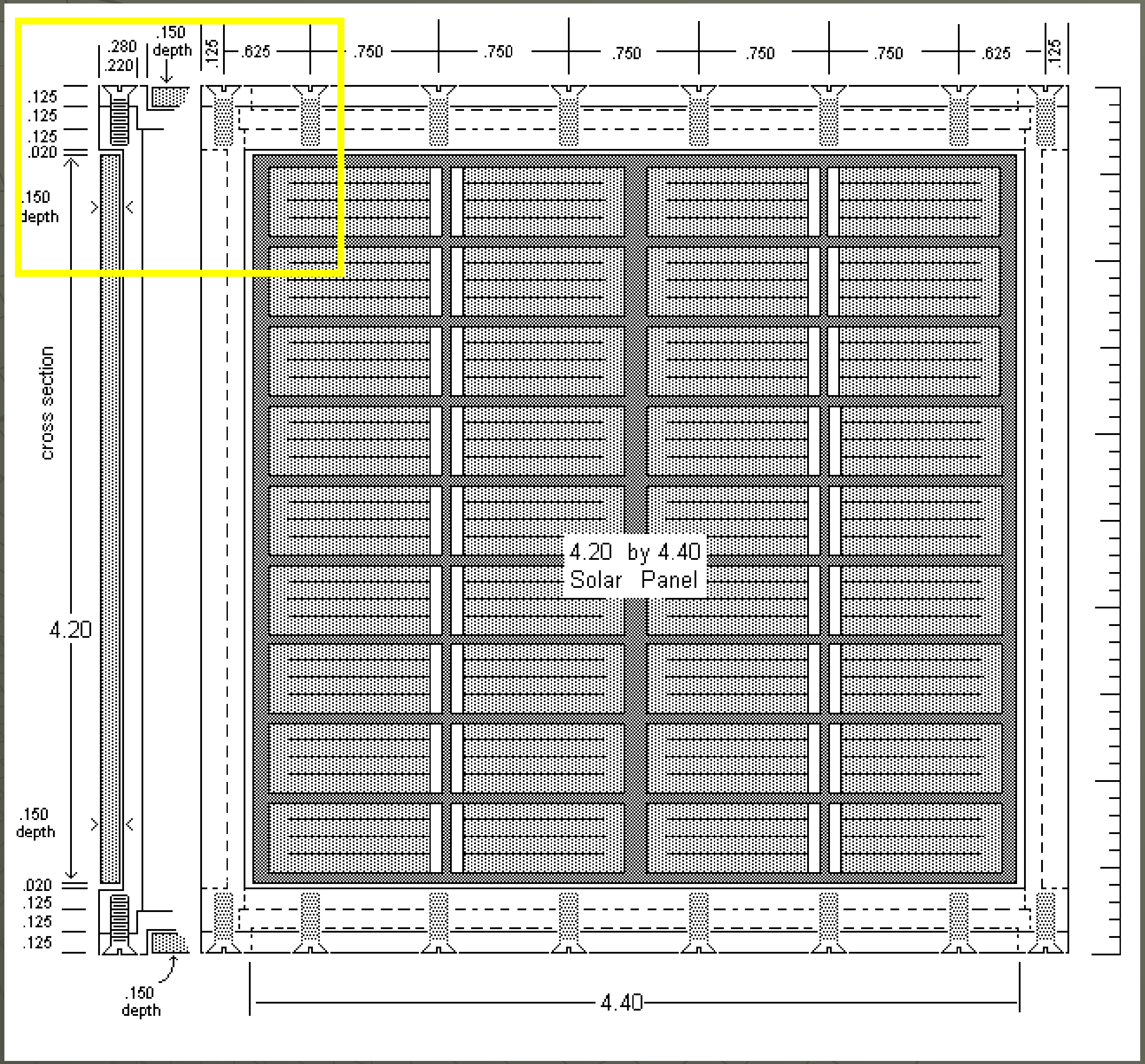


VHF Antenna holes

HF whip hole

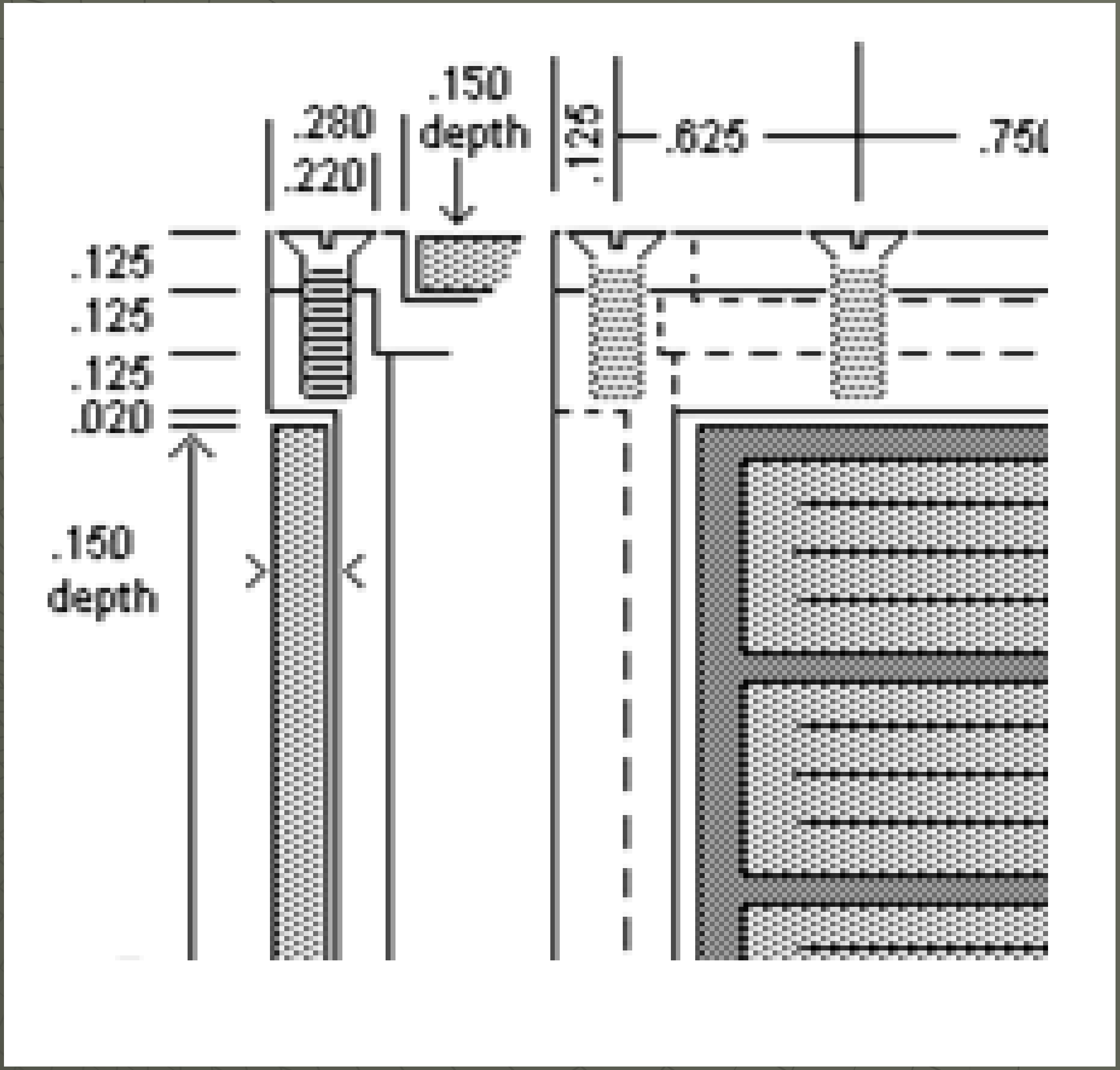
Antenna pockets for other satellite

Side Panel

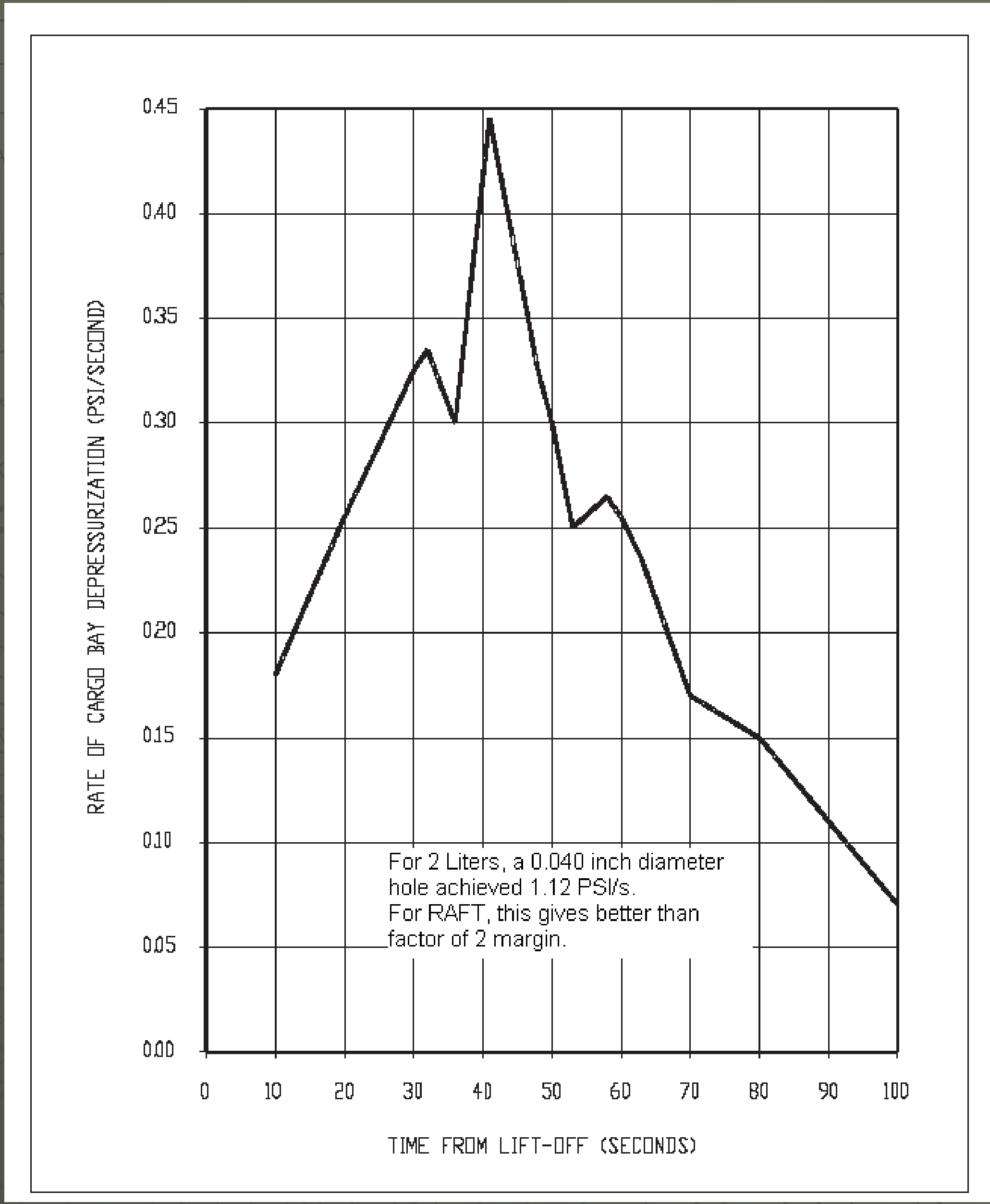


.280
.220
.150
depth
.125
.625
.750
.750
.750
.750
.750
.625
.125
.125
.125
.125
.020
.150
depth
cross section
4.20
4.20 by 4.40
Solar Panel
.150
depth
.020
.125
.125
.125
.150
depth
4.40

Side Panel Close



Depressurization Rate

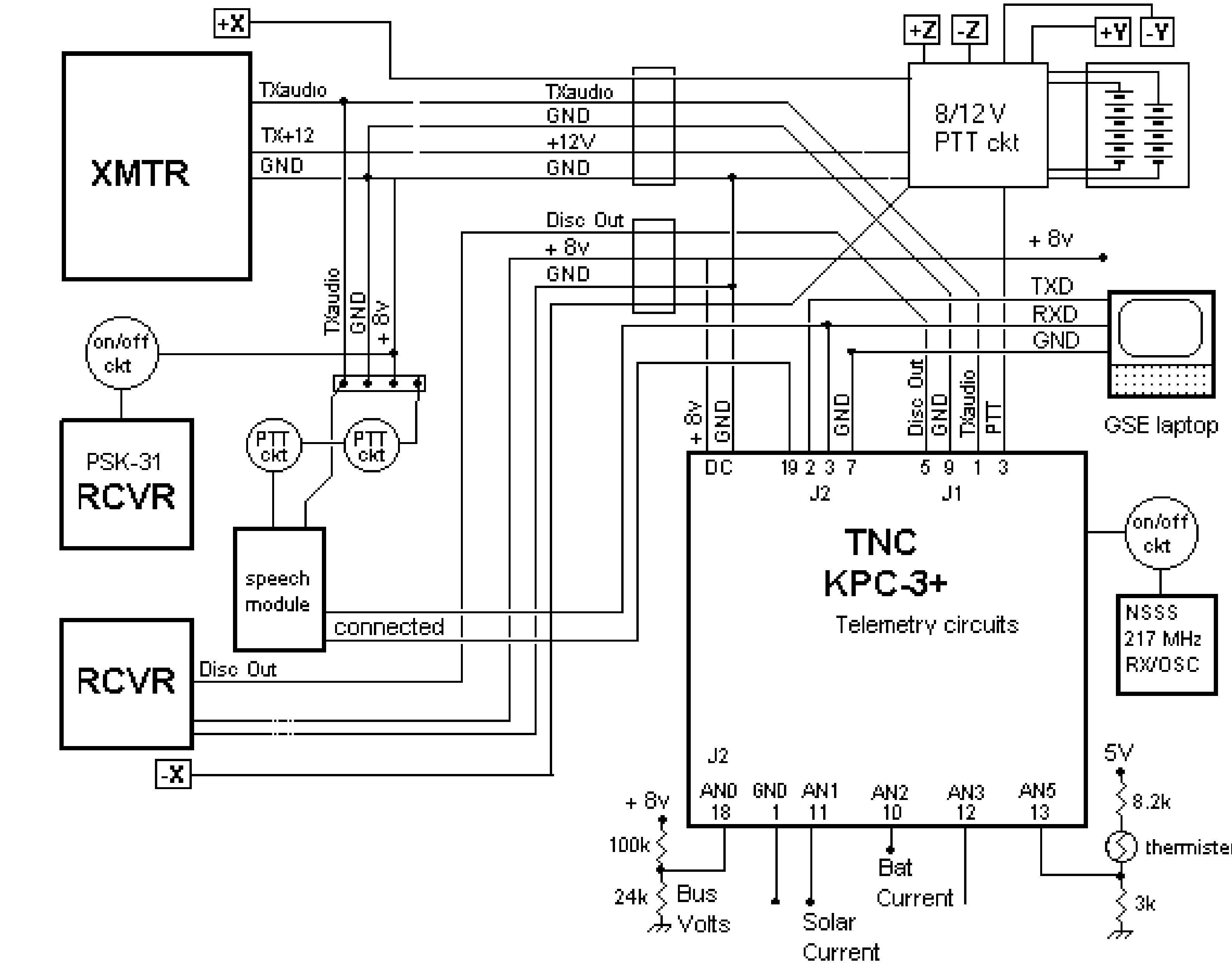


.040 hole

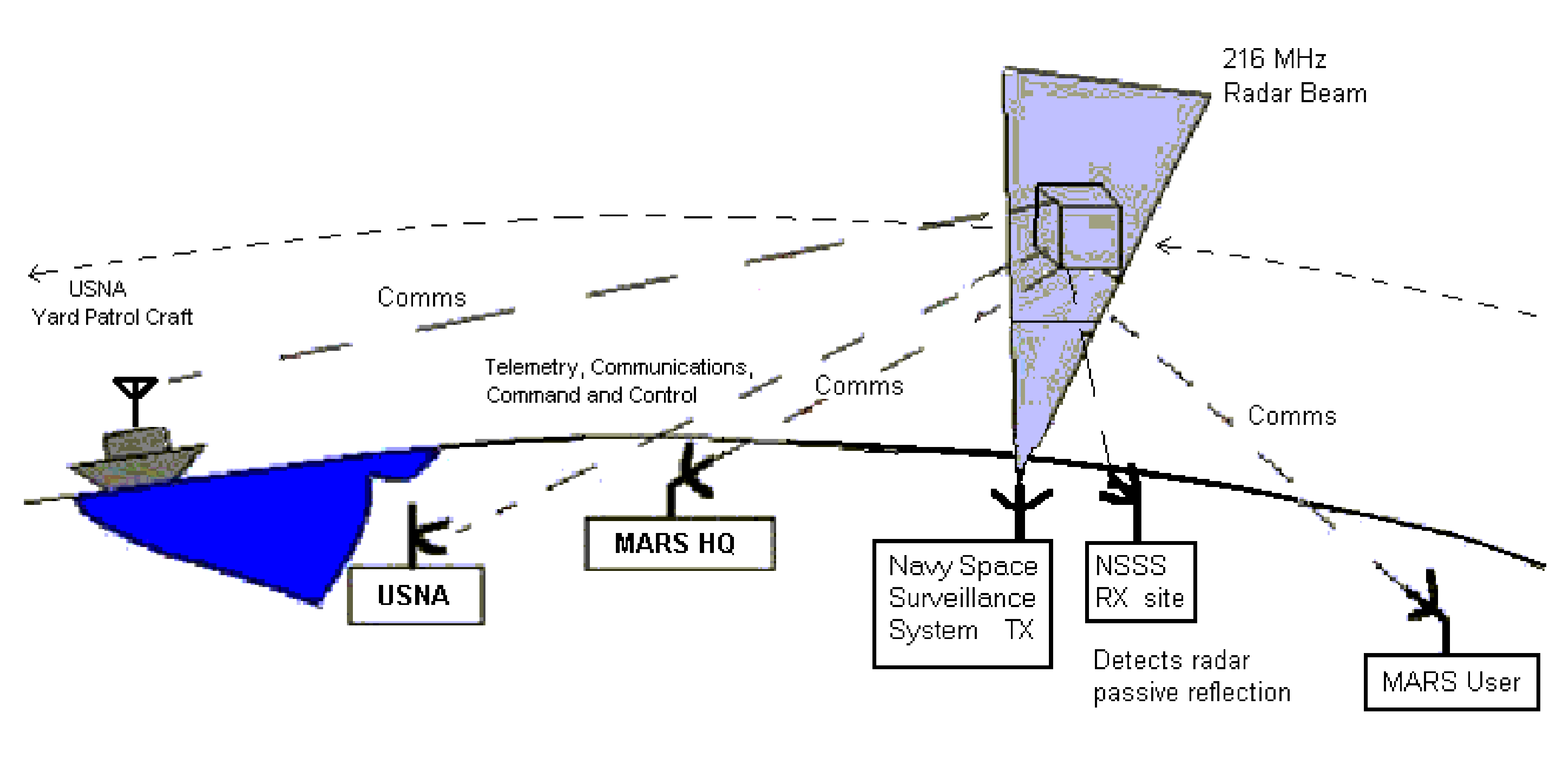
Gives 2:1 margin for depresurization

RAFT1 Schematic

PRELIMINARY



MARScom Mission Architecture



Military Affiliate Radio System

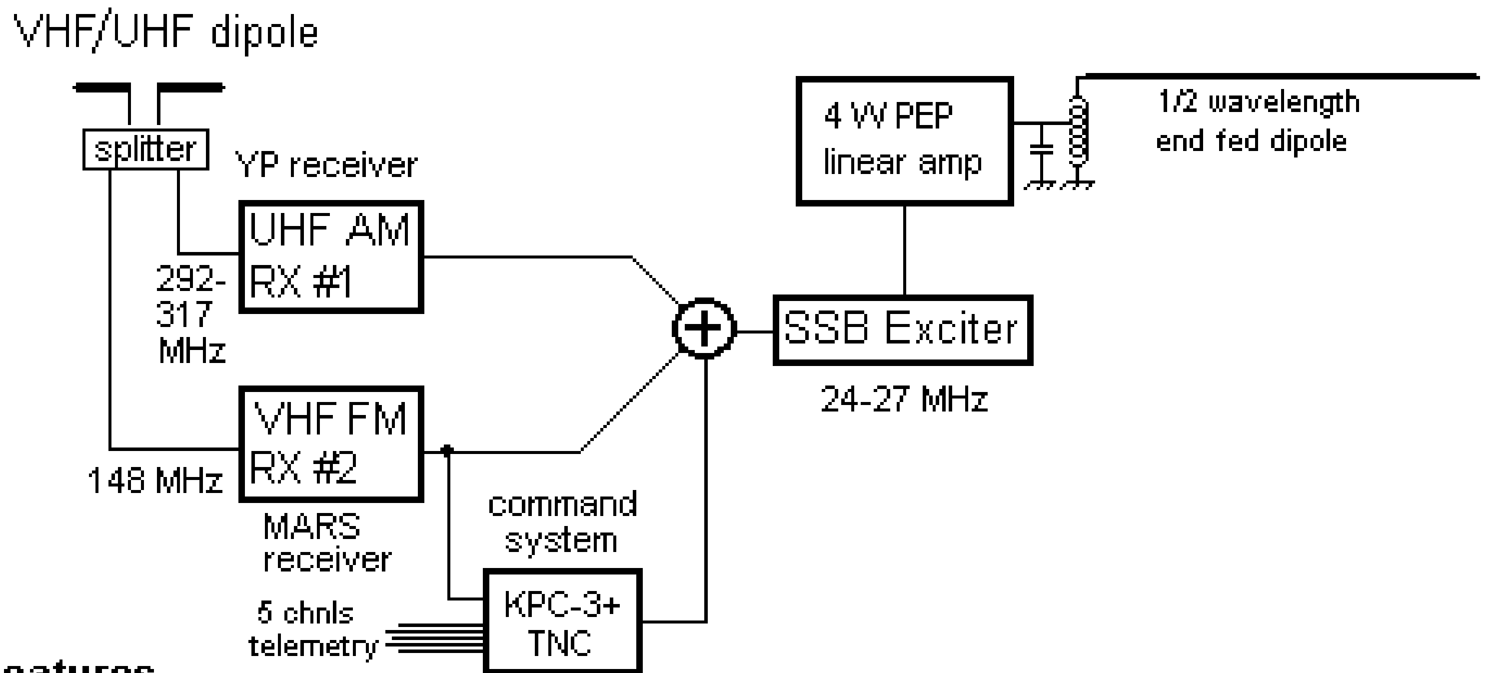
The Mission of the MARS system is to:

- Provide auxiliary communications for military, federal and local disaster management officials during periods of emergency or while conducting drills….
- Assist in effecting normal communications under emergency conditions.
- Handle morale and quasi-official message and voice communications traffic for members of the Armed Forces and authorized U.S. Government civilian personnel
- Provide, during daily routine operations, a method of exchanging MARSGRAMS and … contacts between service personnel and their families back home.

Yard Patrol Craft Application

MARScom Block Diagram

MARScom Voice Transponder



Features

- UHF AM receiver makes MARScom compatible with ALL older UHF transmitters

RAFT Deployment

Velocity of CM:

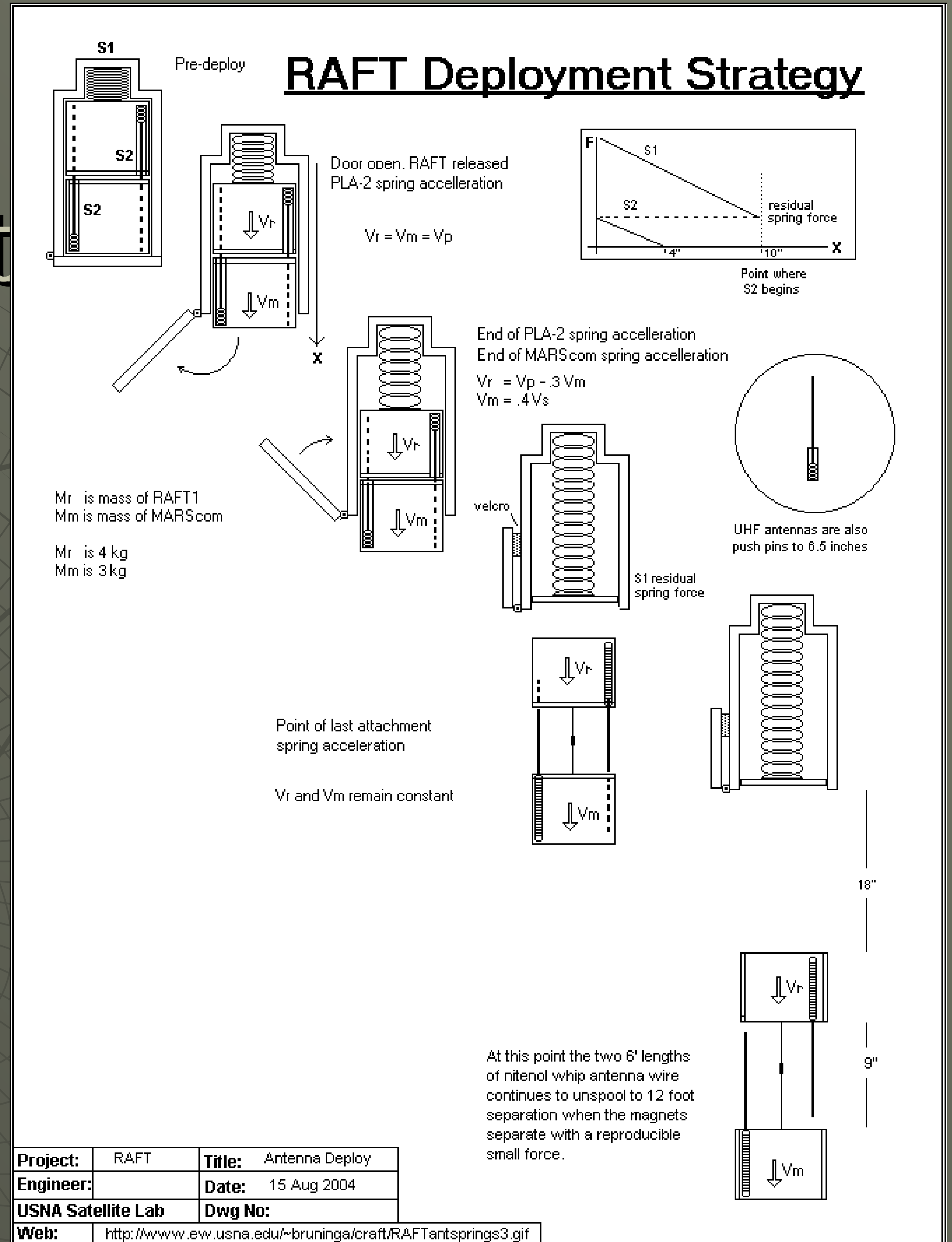
1.00 m/s

Velocity of RAFT:

0.57 m/s

Velocity of MARScom:

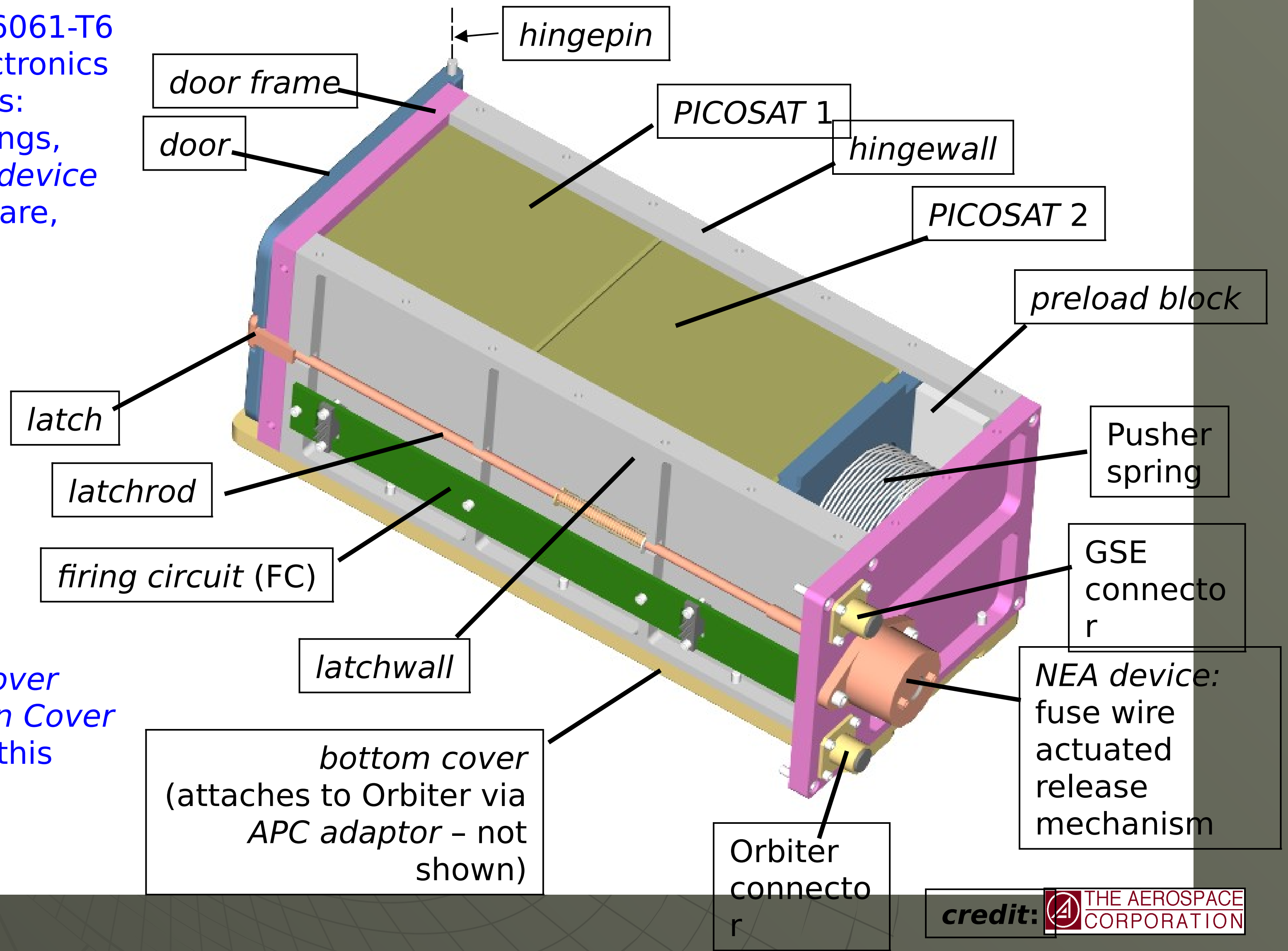
1.57 m/s



Air Track Separation Test

SSPL4410 LAUNCHER: Main Components

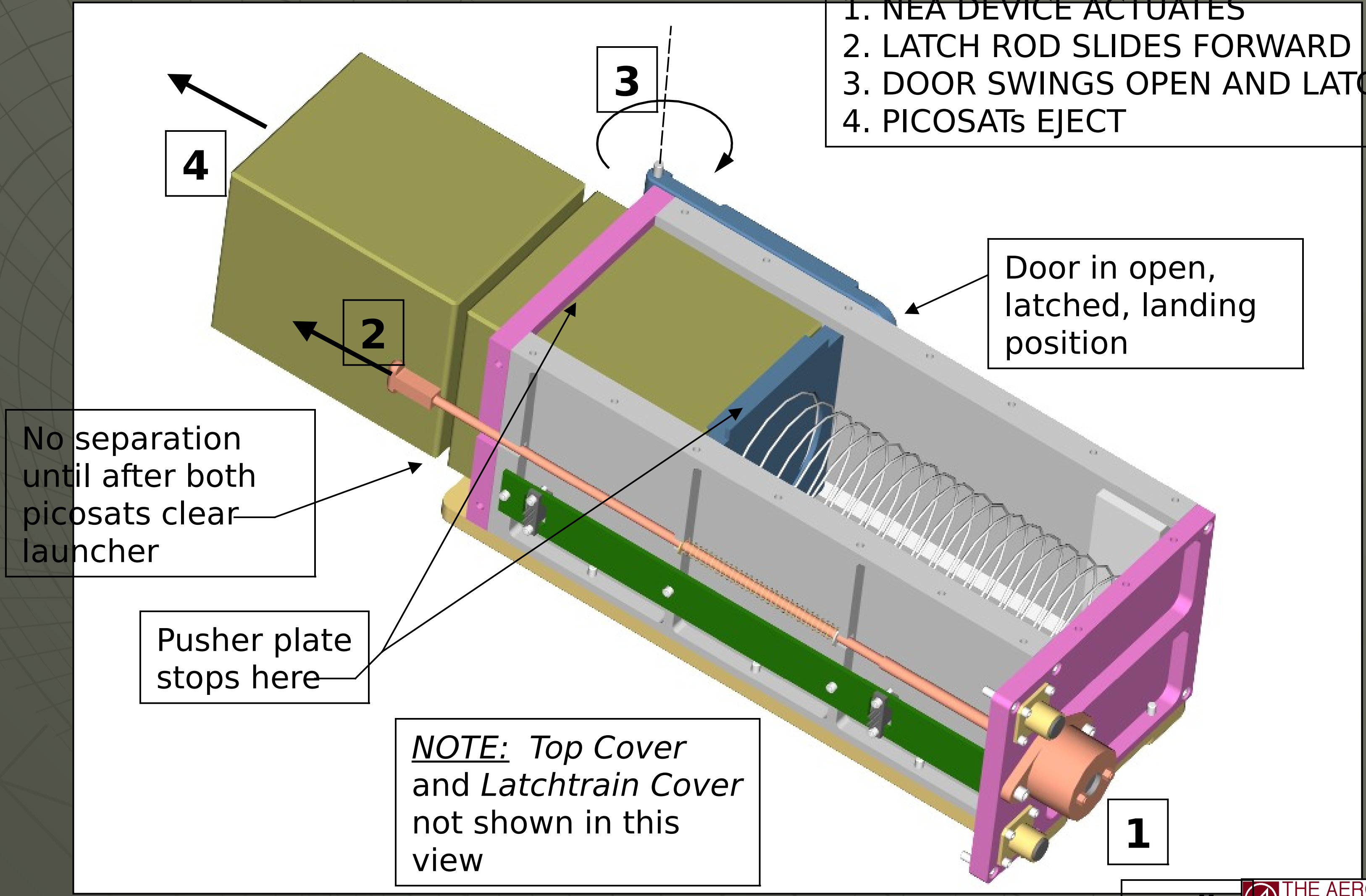
MATERIALS:
All aluminum 6061-T6 except for electronics and CRES parts: fasteners, springs, *latchrod*, *NEA device* internal hardware, *hingepin*



NOTE: Top Cover and *Latchtrain Cover* not shown in this view

SSPL4410 LAUNCHER: Operation

1. NEA DEVICE ACTUATES
2. LATCH ROD SLIDES FORWARD
3. DOOR SWINGS OPEN AND LATCHES
4. PICOSATs EJECT

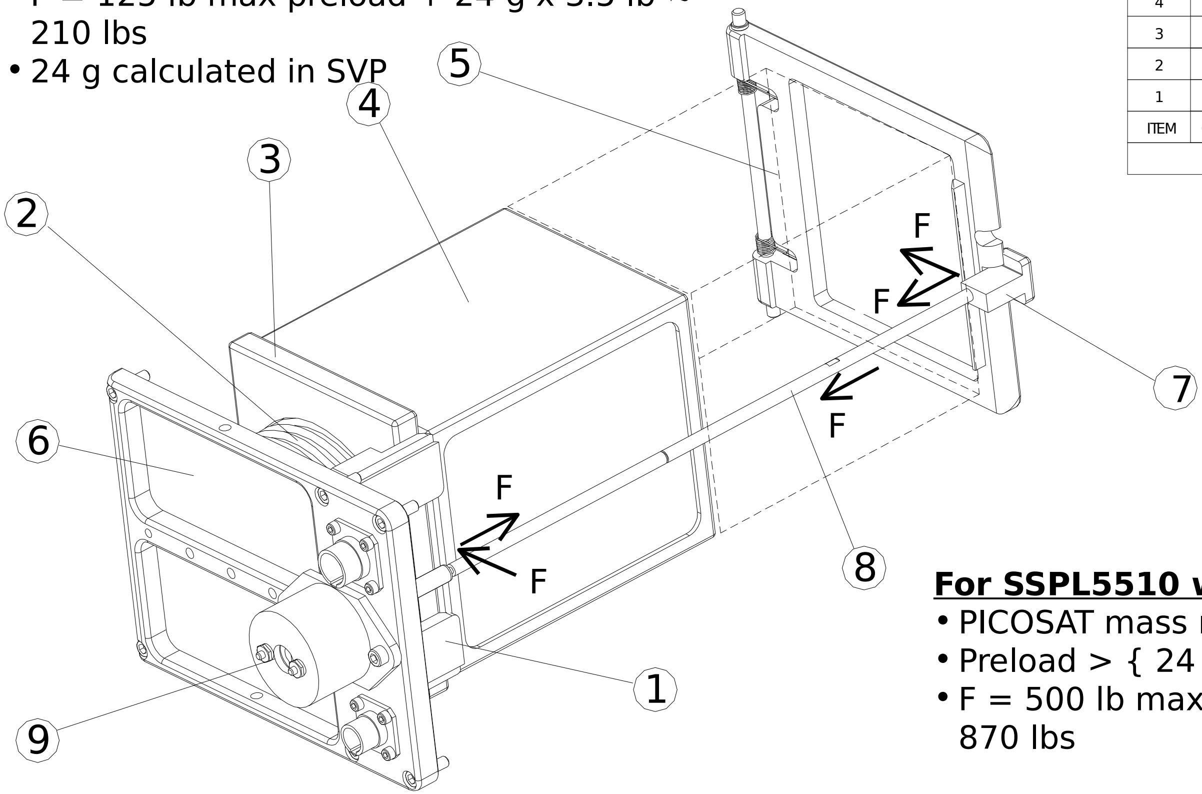


credit: THE AEROSPACE CORPORATION

SSPL4410 LAUNCHER: Preload and Launch Loads

For SSPL4410 with MEPSI:
- PICOSAT mass m = 1.6 kg = 3.5 lbs
- Preload > { 24 g x 3.5 lbs = 84 lbs }
- F = 125 lb max preload + 24 g x 3.5 lb ≈ 210 lbs
- 24 g calculated in SVP

9	1	NEA DEVICE
8	1	LATCHROD
7	1	LATCH
6	1	BACK COVER
5	1	DOOR
4	2	PICOSAT
3	1	PUSHER
2	1	MAINSPRING
1	2	PRELOAD BLOCK
ITEM	QTY	DESCRIPTION
PARTS LIST		

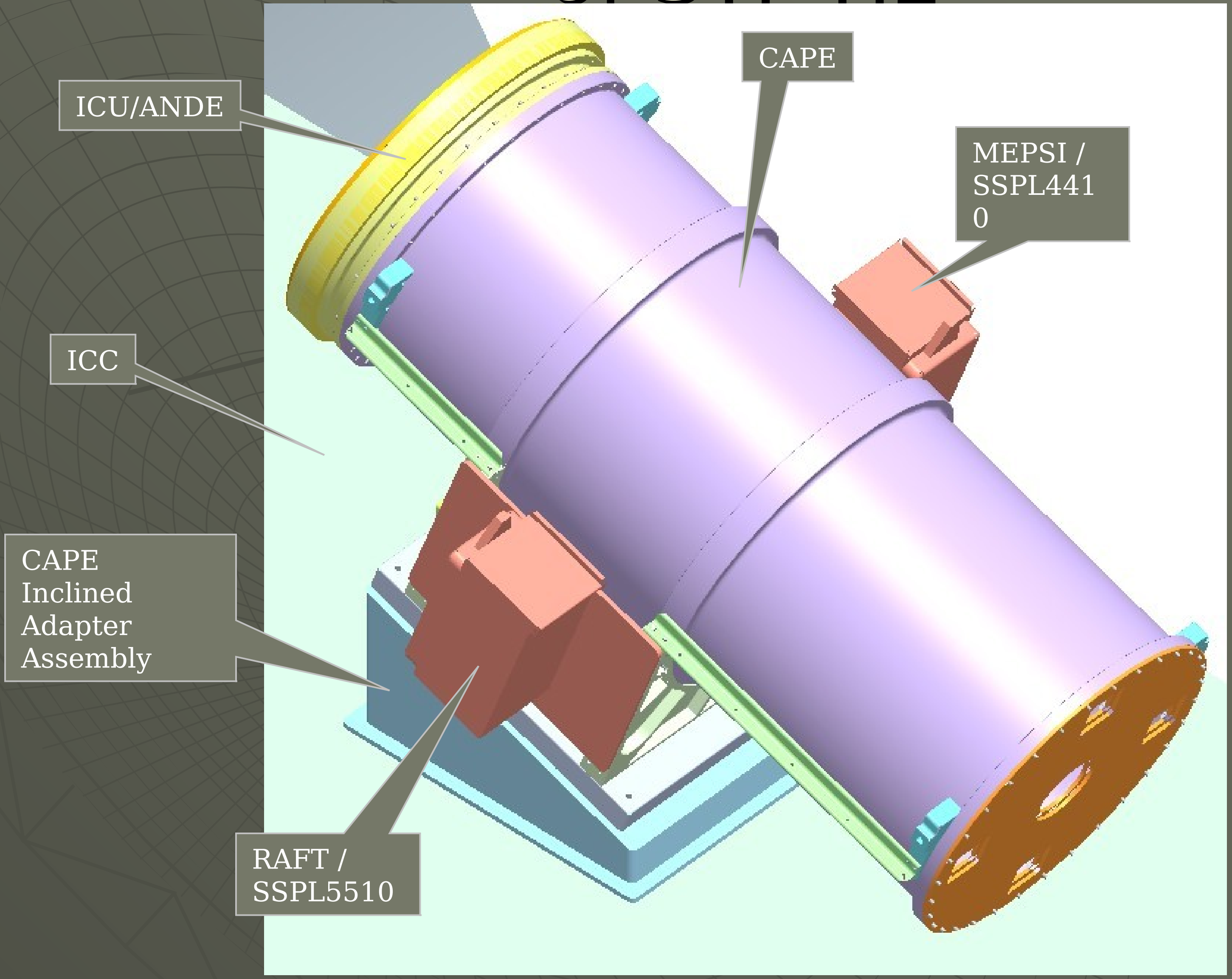


For SSPL5510 with RAFT:
- PICOSAT mass m = 7 kg = 15.4 lbs
- Preload > { 24 g x 15.4 lbs = 370 lbs }
- F = 500 lb max preload + 24 g x 15.4 lb ≈ 870 lbs

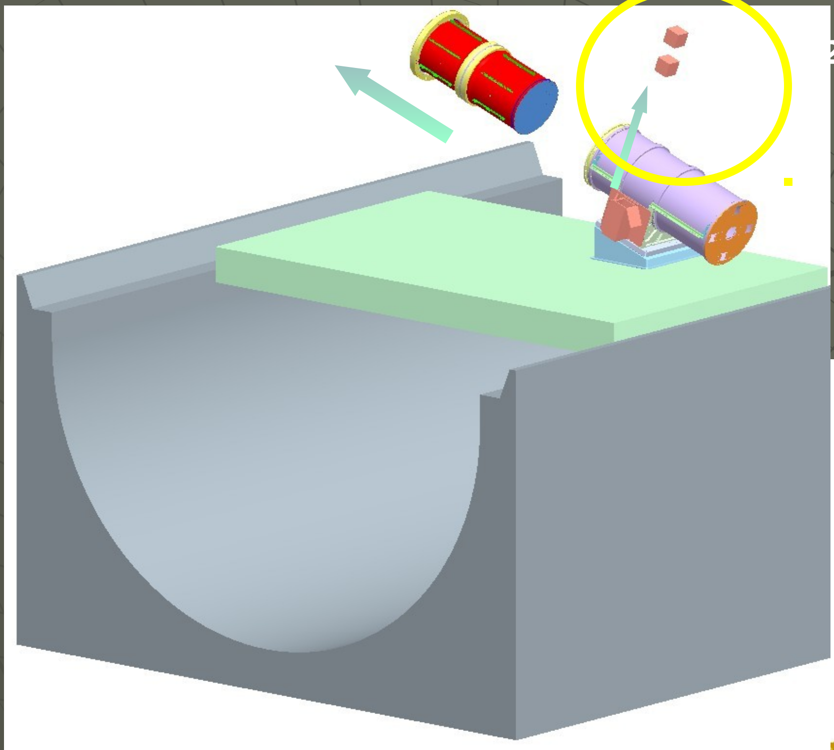
* FRONT PICOSAT NOT SHOWN BUT IS IDENTICAL TO REAR PICOSAT AND REPRESENTED WITH HIDDEN LINES

credit: THE AEROSPACE CORPORATION

STS-116 Configuration: RAFT as Part of STP-H2

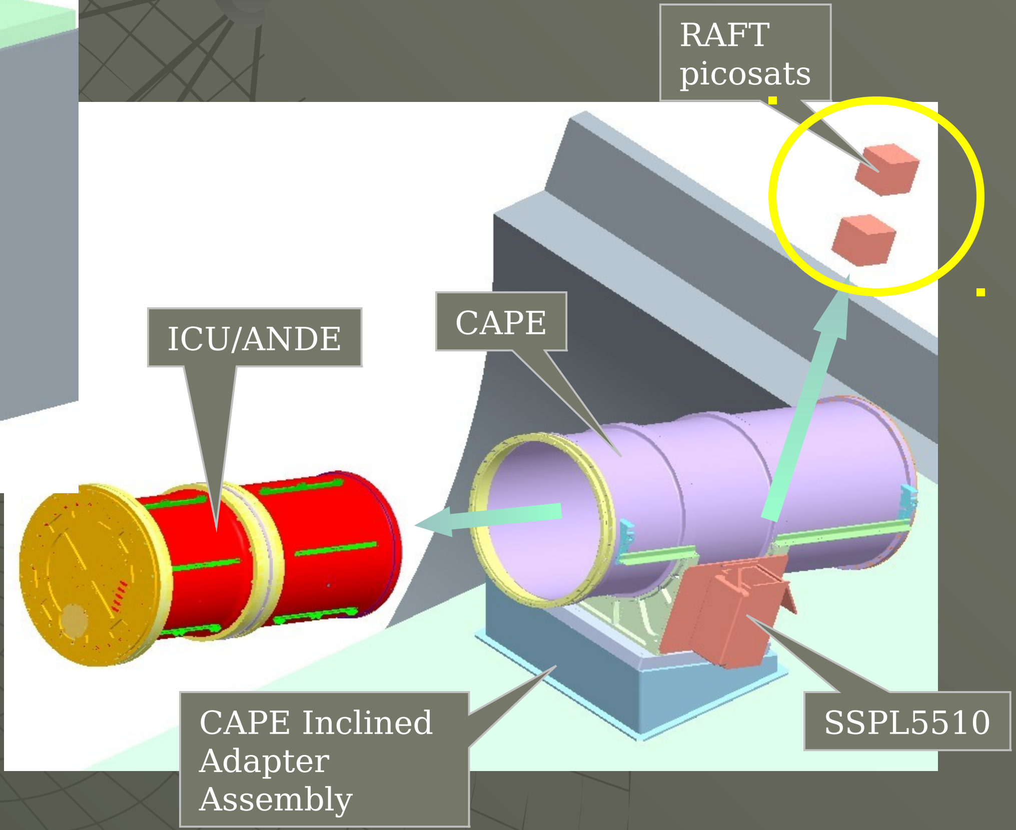


STS-116 Configuration: RAFT as Part of STP-H2



2) ***Deployment of RAFT picosats from SSPL5510***

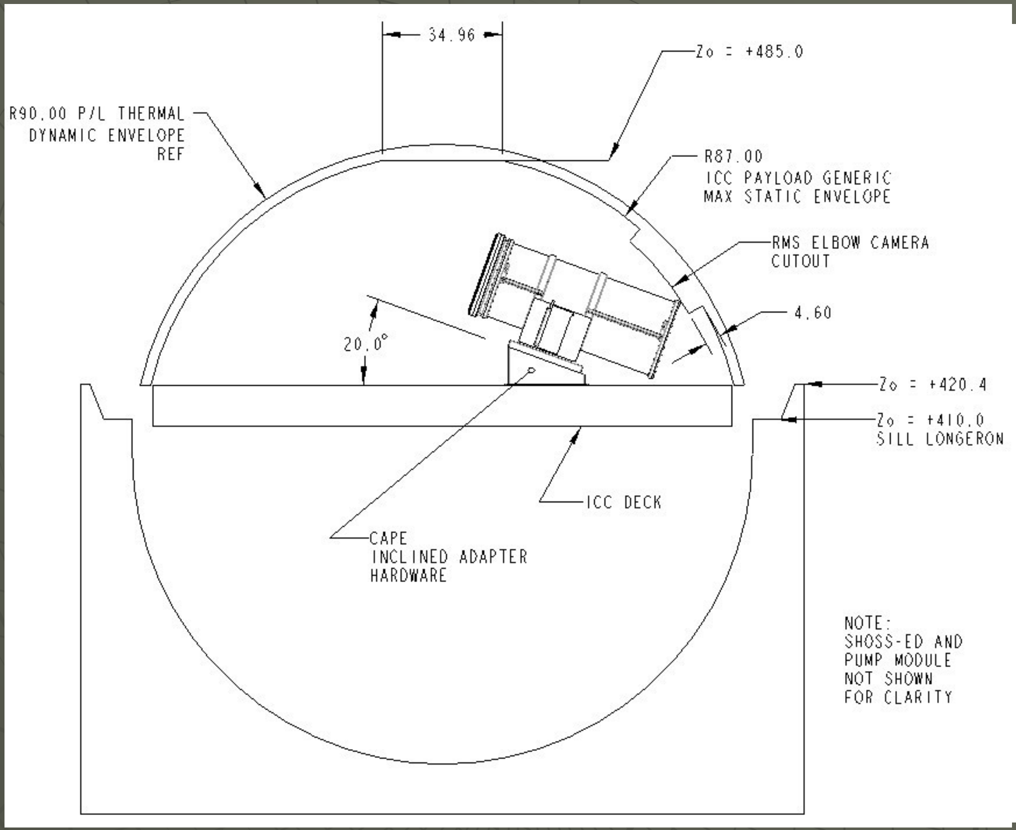
3) ***Deployment of MEPSI picosats from SSPL4410***

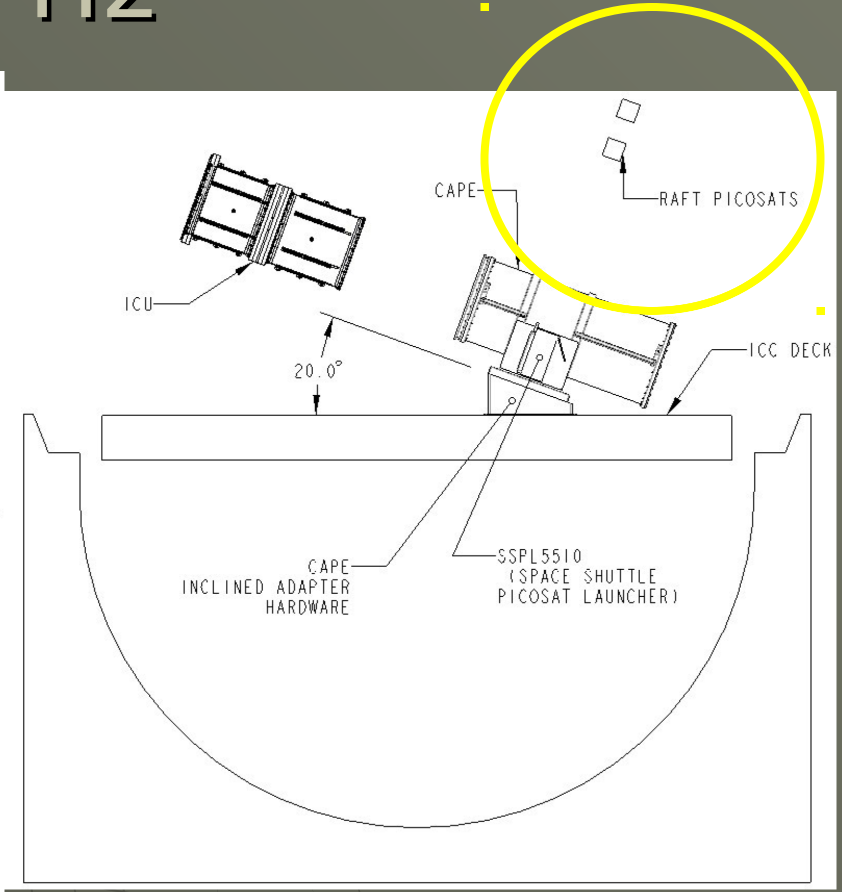


NOTES:

- Non-simultaneous deployment occurs following undock from ISS, not necessarily in the order shown.
- Remaining ICC complement not shown for clarity
- MEPSI/SSPL4410 not shown

STS-116 Configuration: RAFT as Part of STP-H2

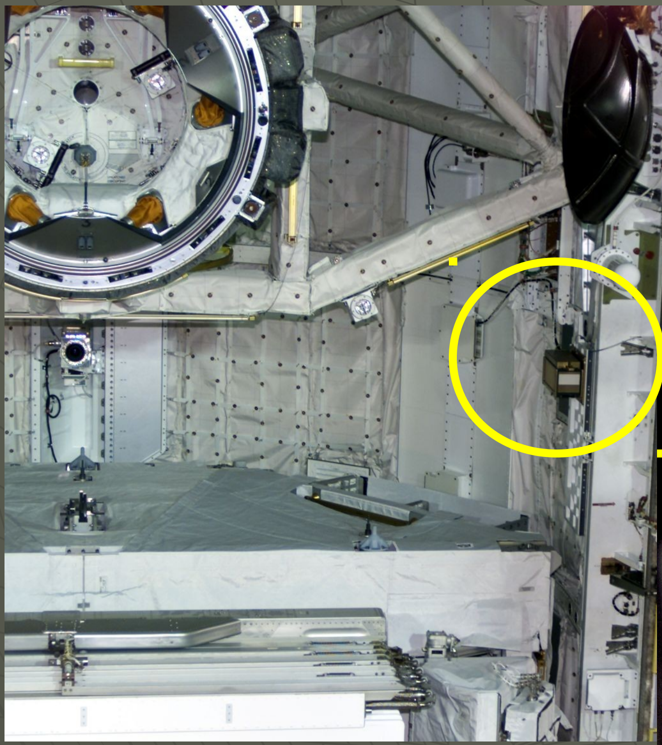


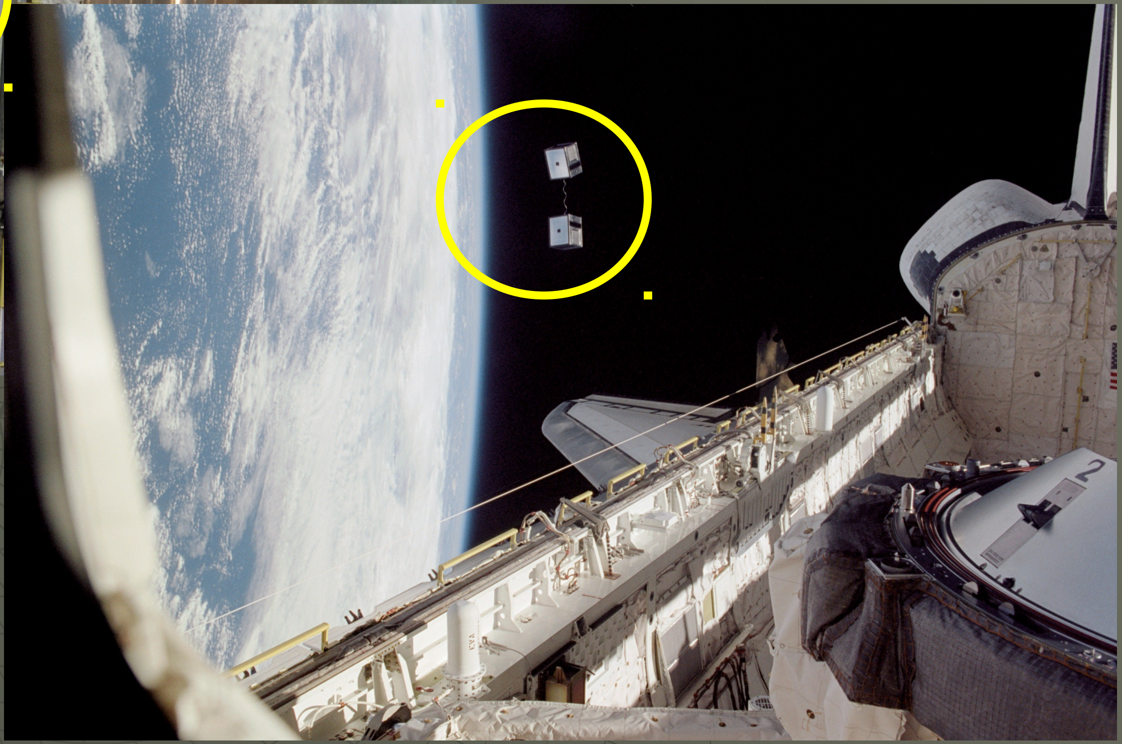


Pre- Deployment

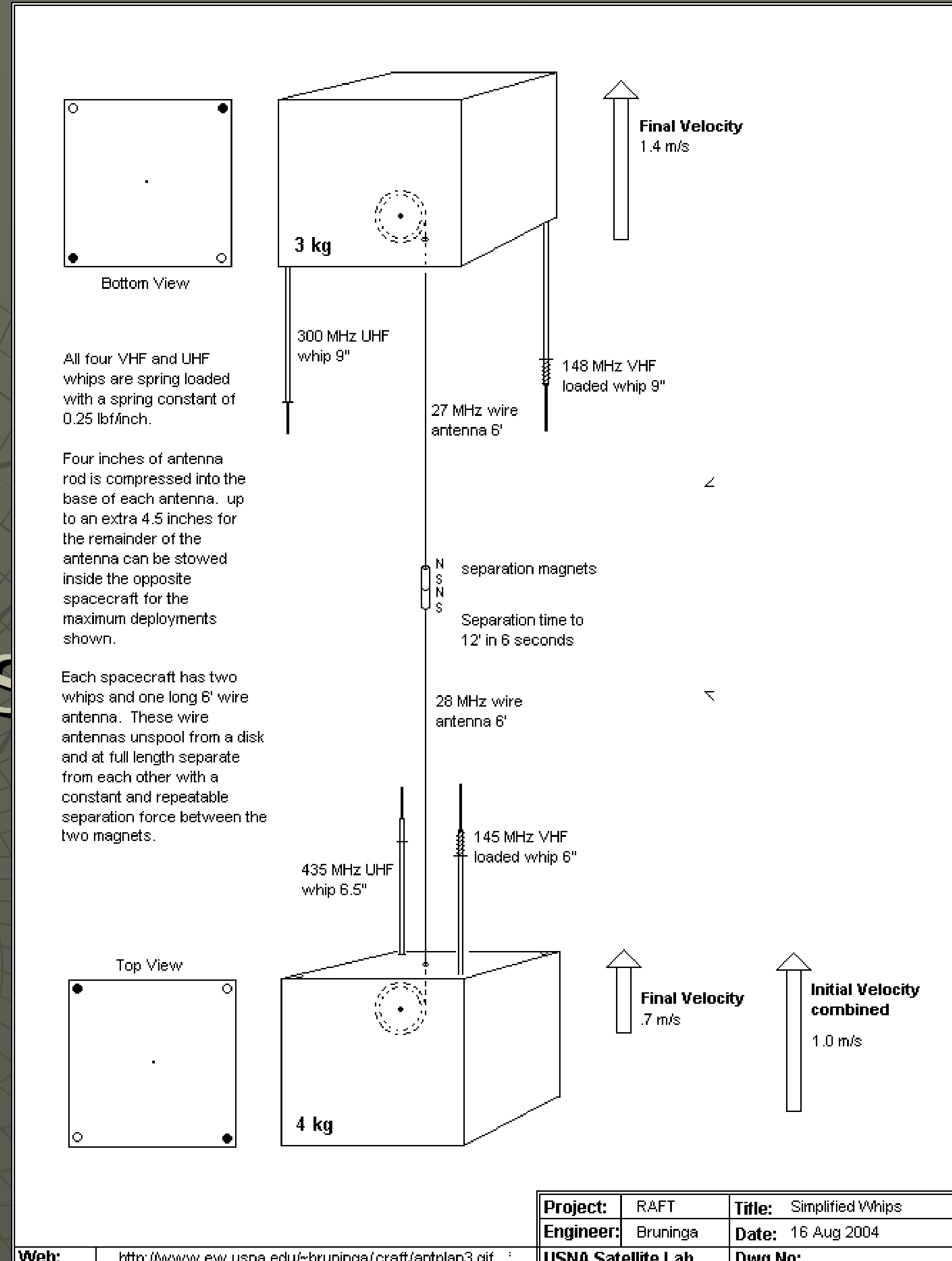
At Deployment

STP PICOSat Launcher Mark II

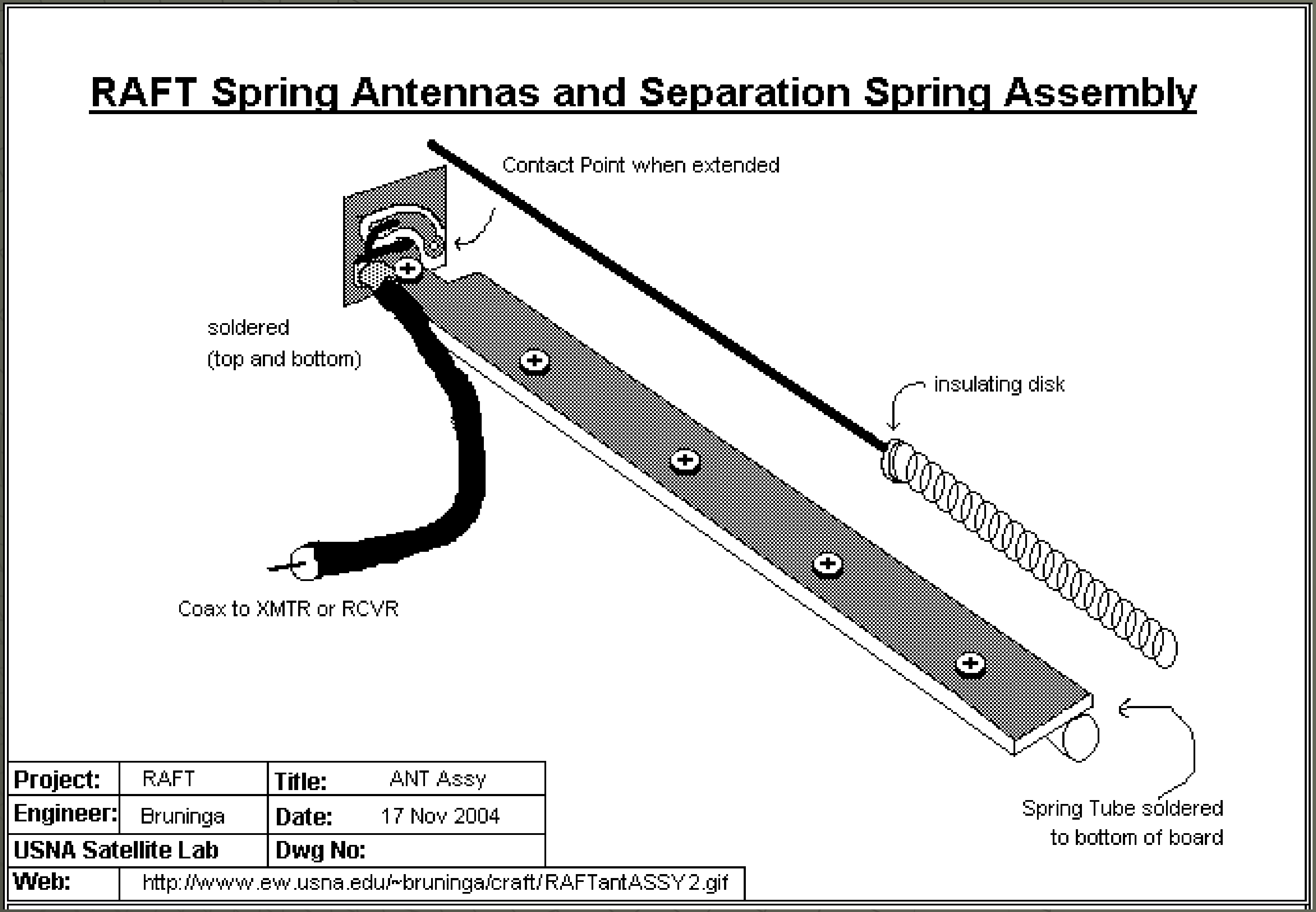




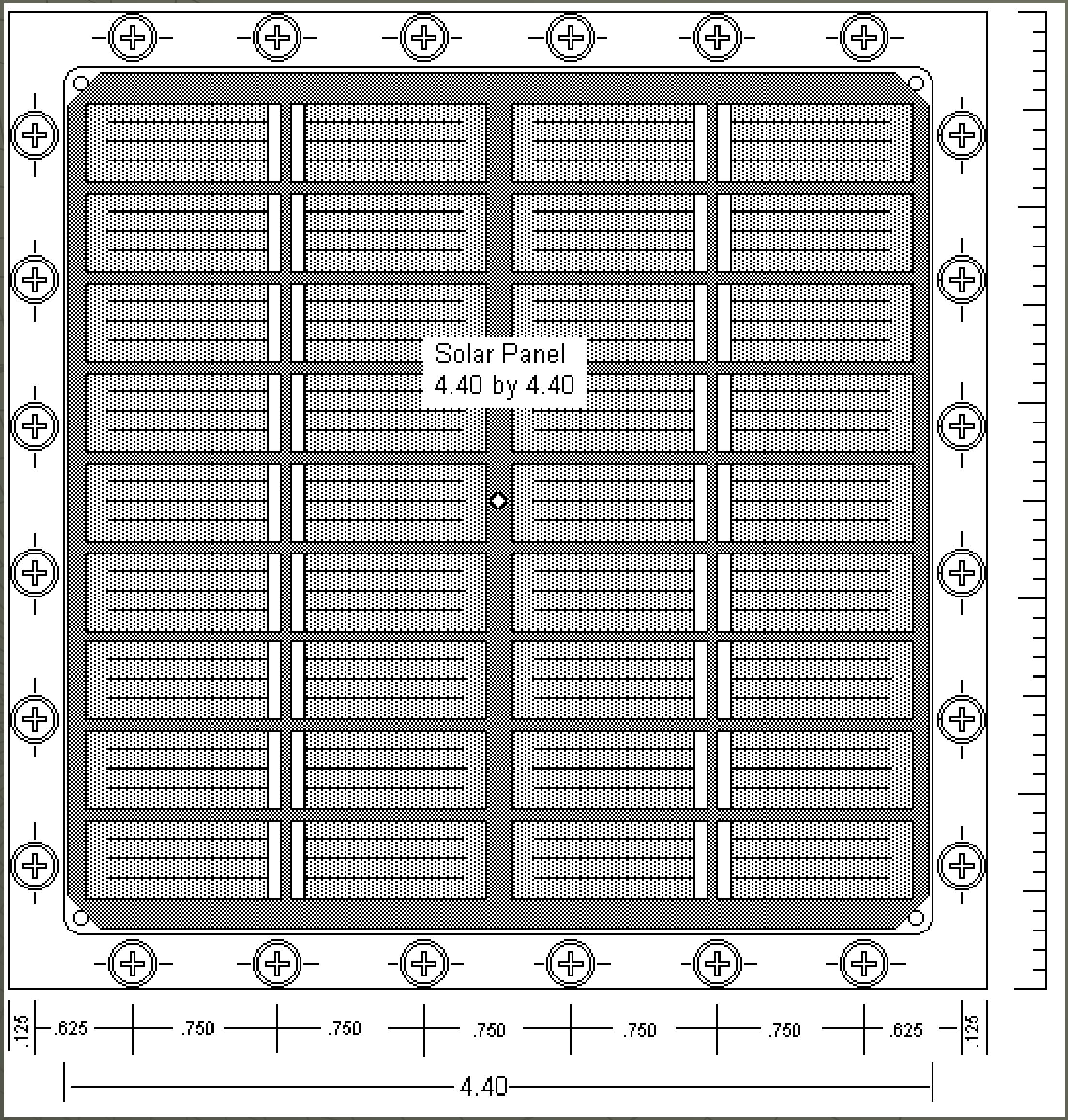
RAFT Antenna Separation Mechanisms



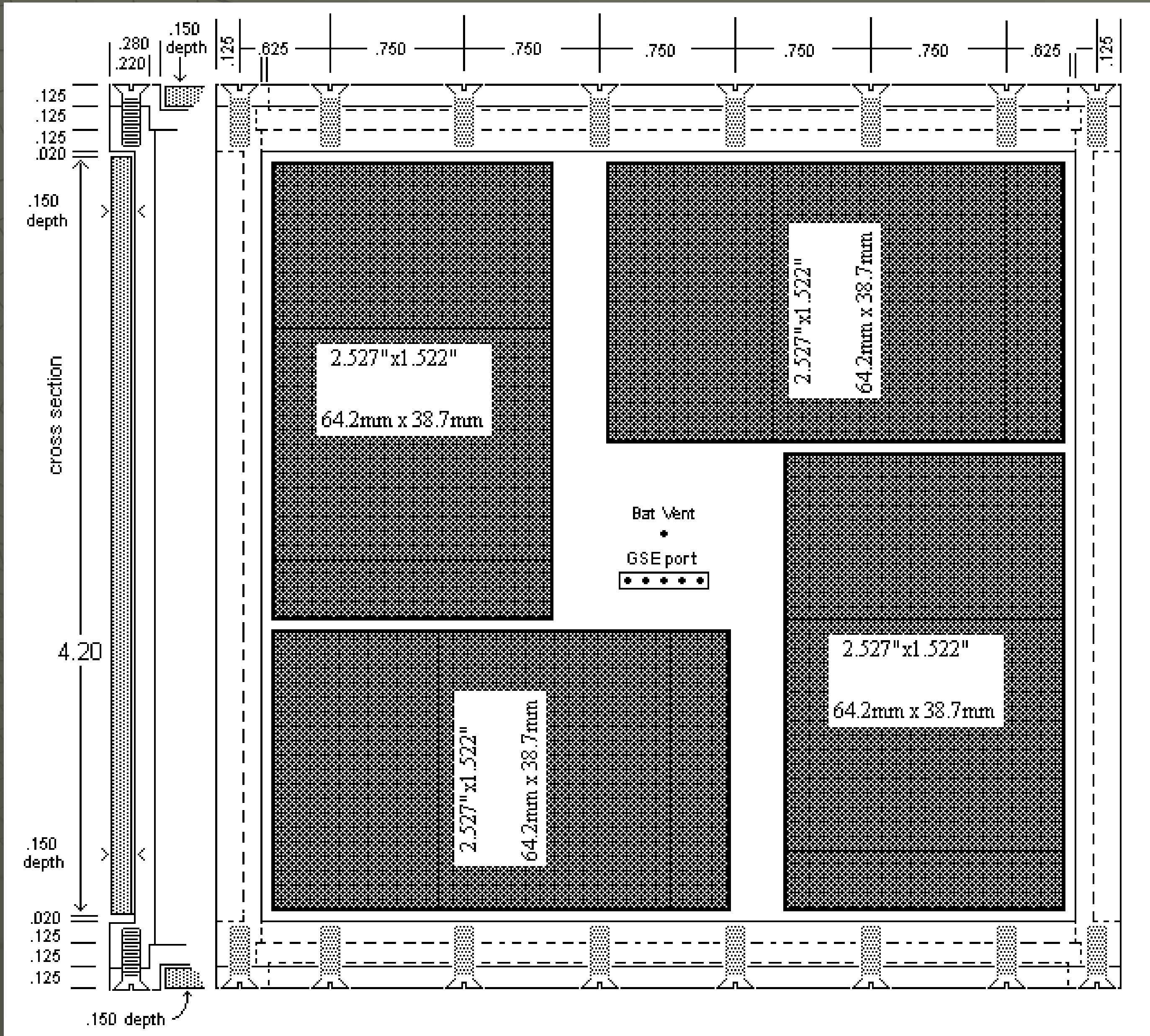
RAFT Antenna Springs



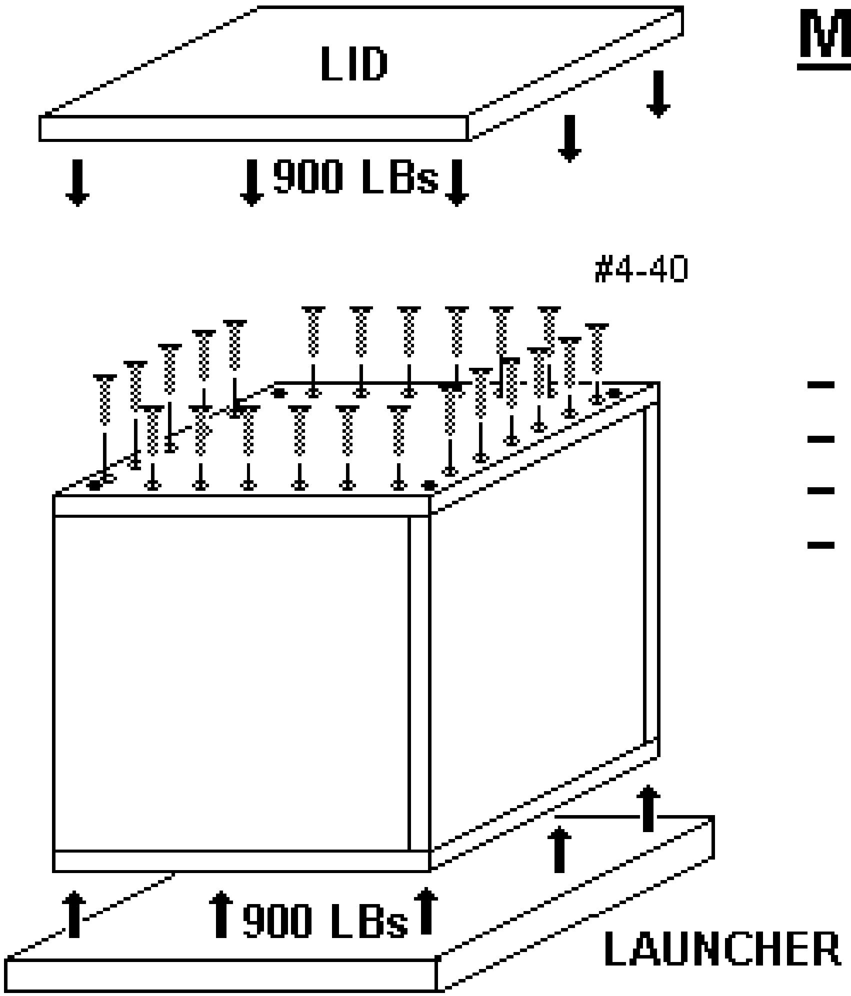
Solar Cell Design



Unique Side Panel for Antenna Crank



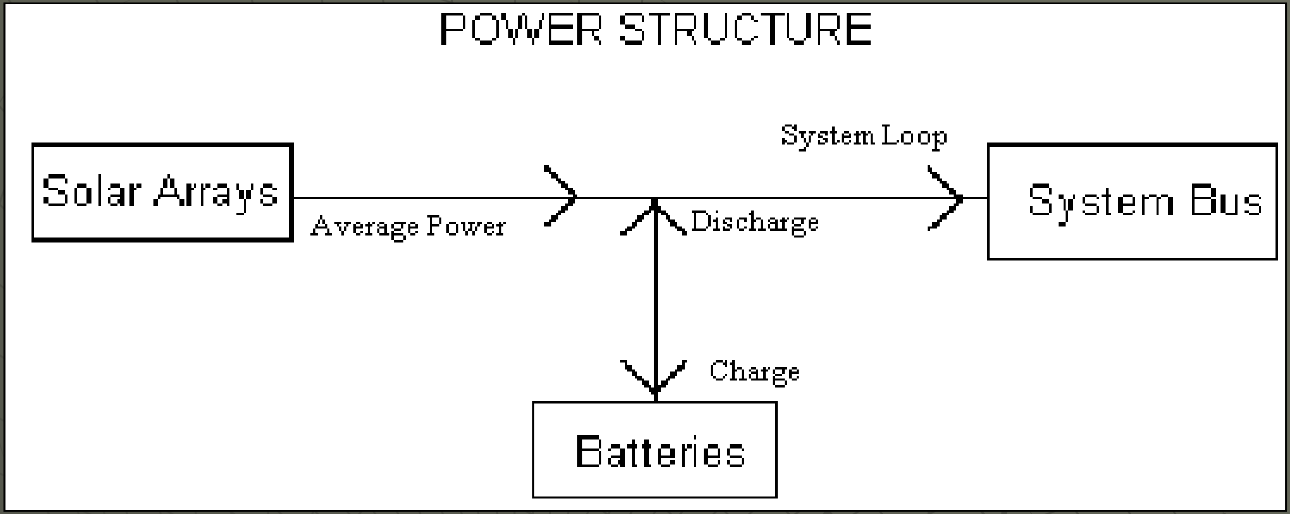
Assembly

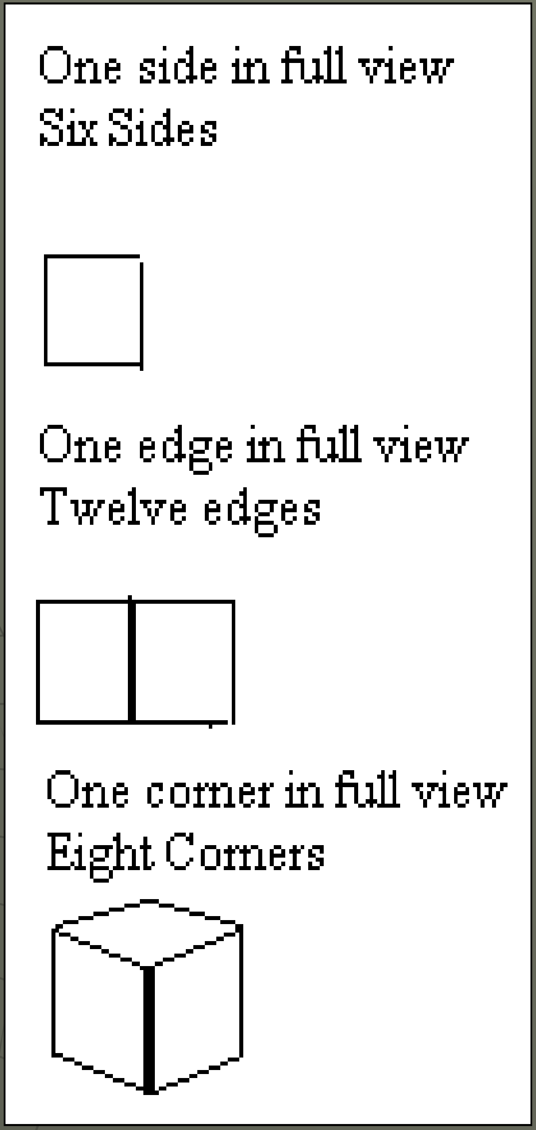


MECHANICAL & FASTENERS

- Four equal 1/4" sides
- Two equal 1/4" Top/Bottoms
- Held under 900 LBs compressive load
- Assures:
  - captive screws
  - no lateral fastener failure modes
  - no Launcher failure modes

Solar Power Budget





Computing average solar power for a cube satellite taking weighted average of all 26 possible orientations.

This analysis is for an ISS orbit with a maximum eclipse of 39% with a 25% efficient solar cell.

Solar Power Budget

SC_{eff}=Solar Cell Efficiency	X_e=Eclipse path efficiency
I_d=Elements of Inherent Degradation	L=Bus Load
a=Sun Angle	$P_{BOL}=SC_{eff}*I_d*$SolarConstant
n=number of exposed cells	$P=P_{BOL}*\sin(a)$
A=area of one cell	$P_{totalavg}=P_{avg}1+Pavg2+P_{avg}3$
t=exposure multiple	$P_{total}=P*n*A$
t_{total}=total number of exposures	$x=t/t_{total}$
T_d=Time in Daylight	$P_{avg}=P_{total}*x$
T_e=Time in Eclipse	$L=(P_{totalavg}*X_e*X_d*T_d)/(T_e*X_d+T_d*X_e)$
X_d=Daylight path efficiency	

SC_{eff} (%)	25	25	25
I_d	0.77	0.77	0.77
SolarConstant	1367	1367	1367
P_{BOL} (W/m^2)	263.15	263.15	263.15
a (deg)	90	45	33
P (W/m^2)	263.15	186.07	143.32
n	4	8	12
A (m^2)	0.0028	0.0028	0.0028
P_{total} (W)	2.95	4.17	4.82
t	6	12	8
t_{total}	26	26	26
x	1/4	1/2	1/3
P_{avg} (W)	0.6801	1.9237	1.4817

$P_{totalavg}$ (W)	2.08
T_d	0.61
T_e	0.39
X_e	0.65
X_d	0.85
L (W)	0.96

Conclusion: Using four 25% efficient solar cells per side of the satellite and a 39% eclipse time, an average available bus load of 0.96 watts will be available to the spacecraft

RAFT1 Required Power Budget

	Current (mA)	Normal	Avrg (mA)	PSK-31	Avrg (mA)	STBY	Avrg (mA)
VHF FM TX	500.00	2%	10.00	10%	50.00	1%	5.00
UHF FM RX	30.00	100%	30.00	100%	30.00	100%	30.00
TNC	15.00	100%	15.00	100%	15.00	100%	15.00
Down Converter	50.00	0%	0.00	10%	0.05	0%	0.00
29 MHz RX	50.00	0%	0.00	10%	0.05	0%	0.00
20% Reserve	9.00		9.00		9.00		9.00
Avrg (mA)			64.00		104.10		59.00

	Normal Use	PSK-31	STBY	Available
Avrg(mA)	64.00	104.10	59.00	114.2857
System (Volts)	8.40	8.40	8.40	8.4
Avrg (Watts)	0.5376	0.87444	0.4956	0.96

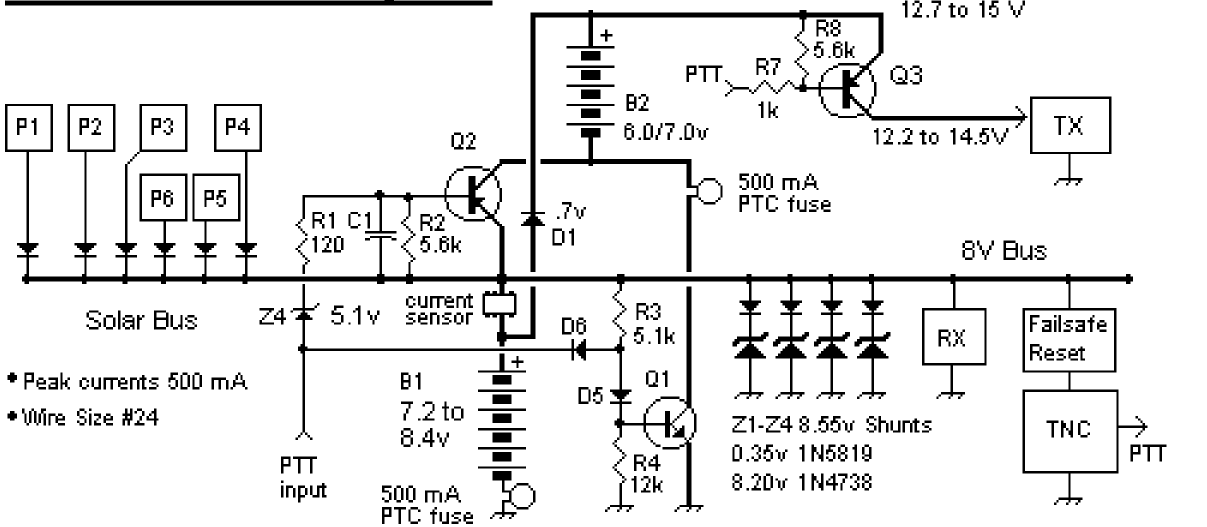
MARScom Required Power Budget

	Current (mA)	Normal	Current (mA)	YPSATCOM	Current (mA)
VHF FM RX	30.00	100%	30.00	100%	30.00
UHF AM RX	30.00	0%	0.00	100%	30.00
SSB Exciter	50.00	8.34%	4.17	8.34%	4.17
1W Linear PA	100.00	8.34%	8.34	8.34%	8.34
Decoder	10.00	100%	10.00	100%	10.00
20% Reserve	8.00		8.00		8.00
Avrg (mA)			60.51		90.51

	Normal Use	YPSATCOM	Avalible
Avrg (mA)	60.51	90.51	114.2857143
System (Volts)	8.40	8.40	8.4
Avrg (Watts)	0.51	0.76	0.96

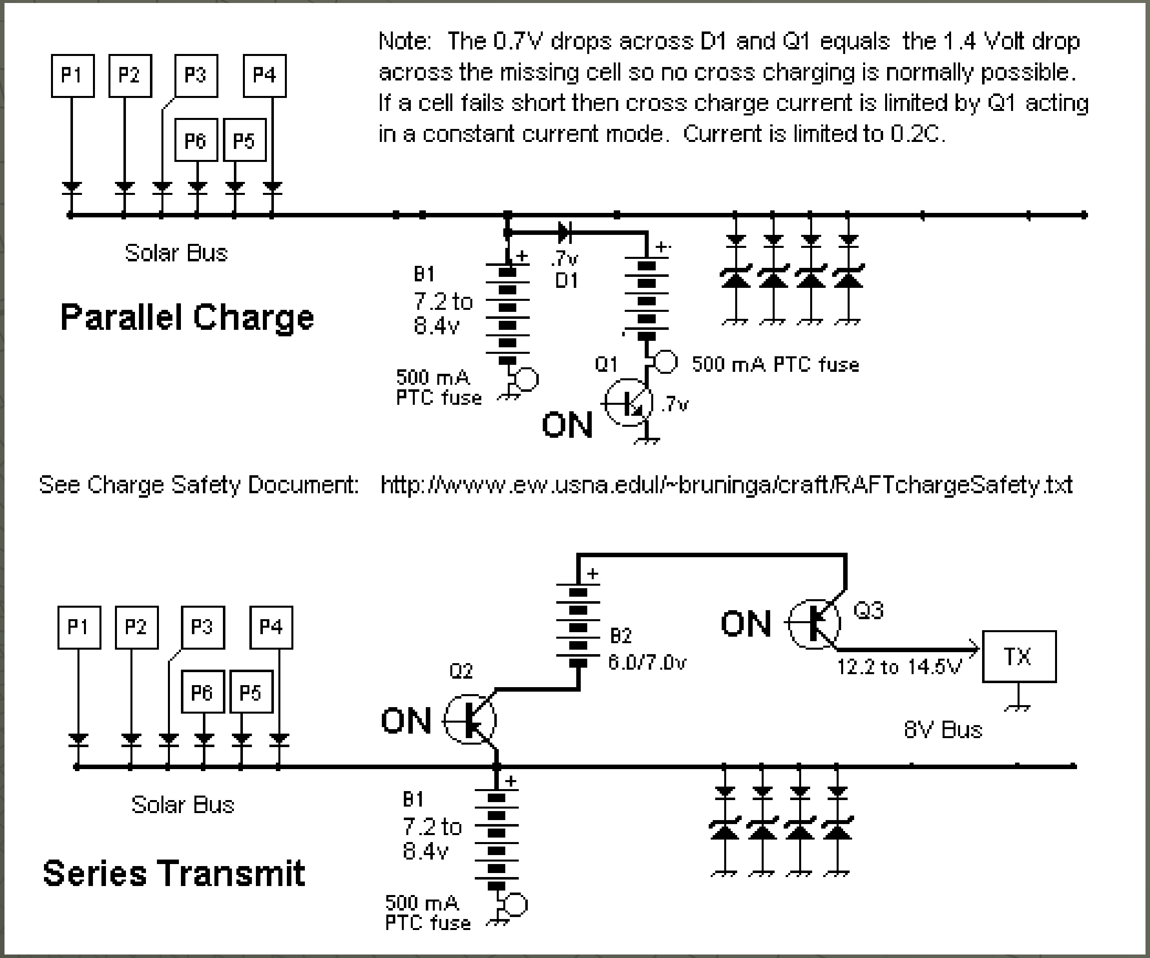
Power System

RAFT 8/12V Power System



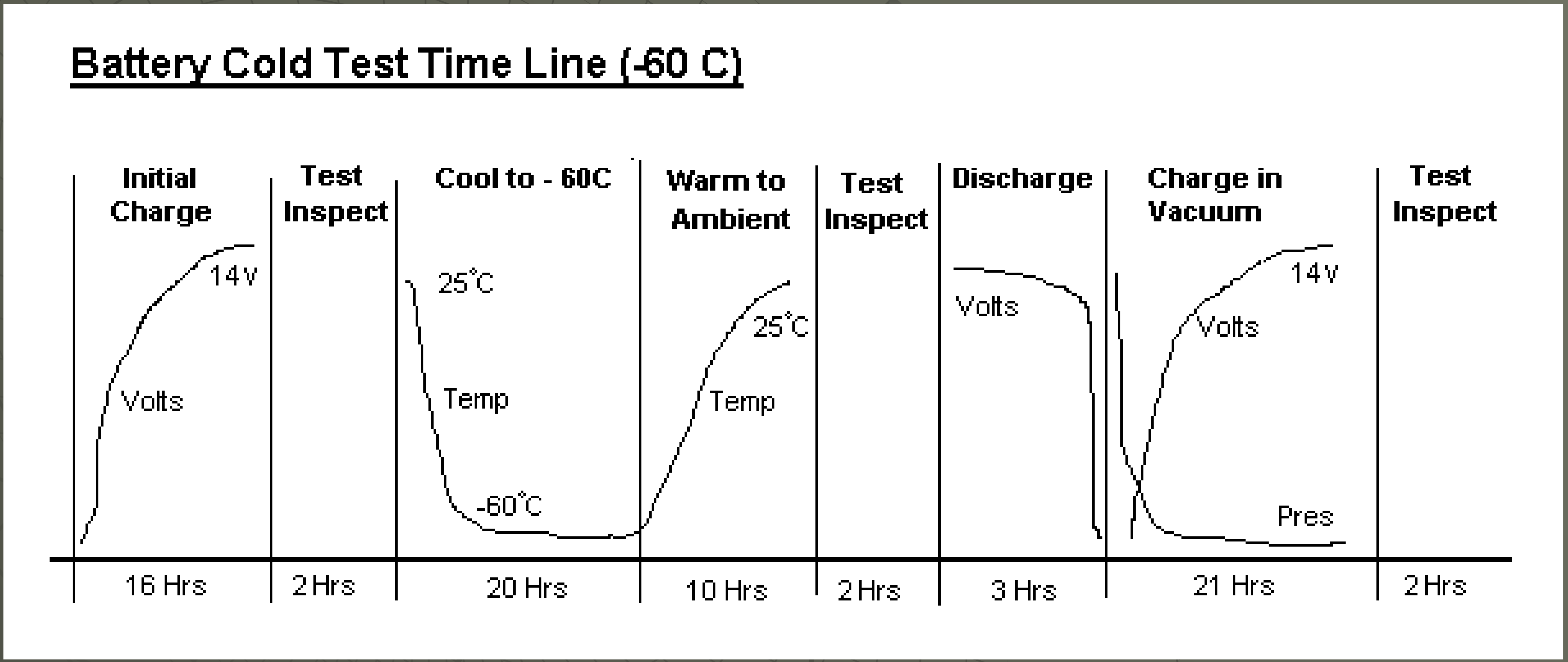
- Battery B1 is 6 cells NiCd feeding 7.2-8.4 unregulated bus to the TNC and Receiver.
- Solar panels provide about 250 mA at 8.5 volts to charge B1 and B2 in parallel via D1 and Q1.
- Q1 is saturated on via R3/D5 during charge. When PTT goes low, D6 pulls Q1 base to OFF via R4
- Excess solar power above 8.55V is shunted via Z1-Z4 leaving about 25 mA to each string
- Z4/R1 and R7 turn ON Q2 and Q3 connecting B1/B2 in series to provide 12 to 14.2 volts to the XMTR.
- The R1-C1 time constant and Zener Z4 assures that both Q1 and Q2 will not be on at the same time.
- Charging efficiency is 91% of normal, discharge efficiency is 98% of normal.

Simplified Power System



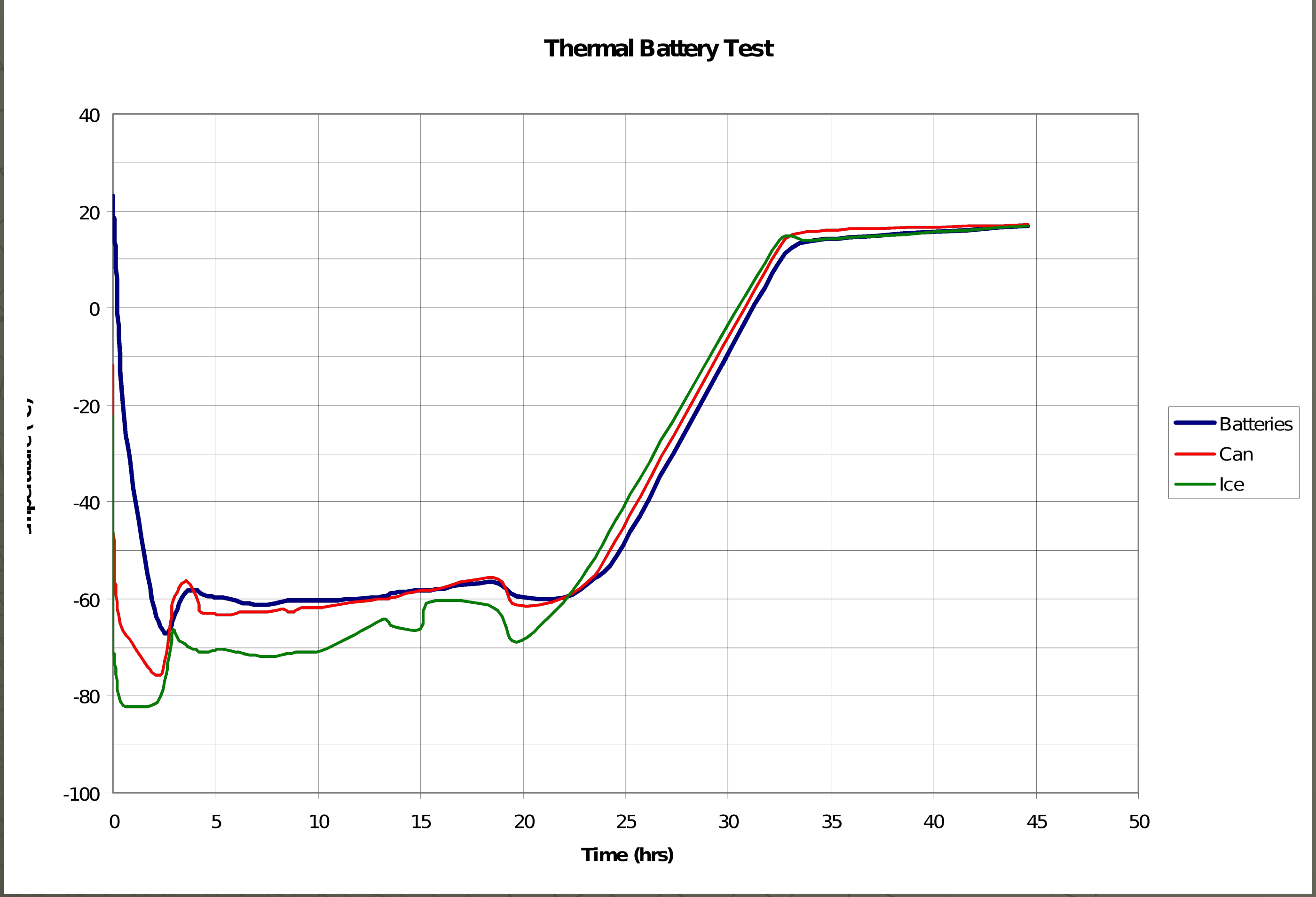
-60 °C Battery Tests

Time Line

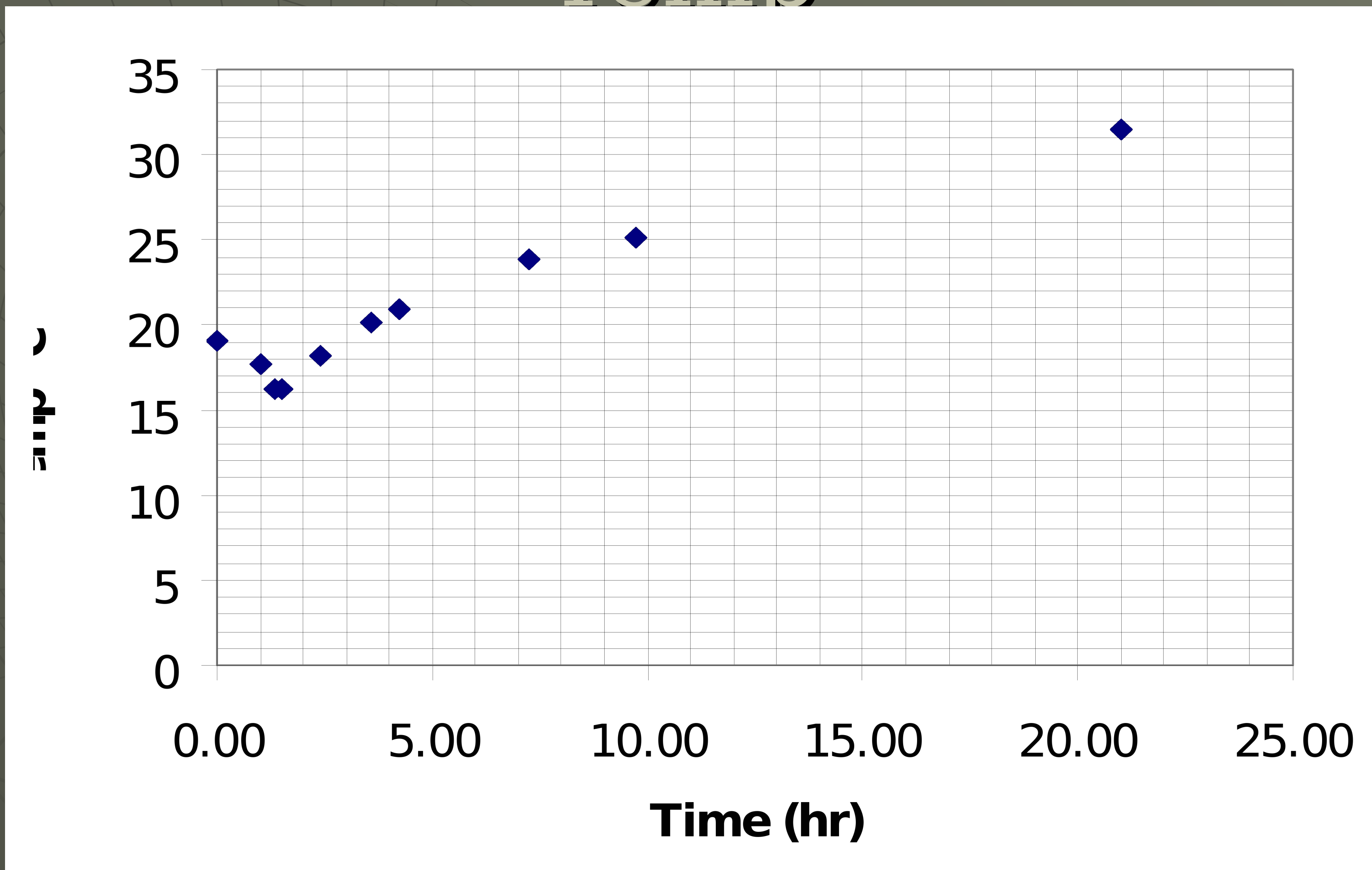


Battery Cold Test Time Line (-60 C)
Initial Charge
Test Inspect
Cool to - 60C
Warm to Ambient
Test Inspect
Discharge
Charge in Vacuum
Test Inspect
14 v
Volts
25°C
Temp
-60°C
25°C
Temp
Volts
14 v
Volts
Pres
16 Hrs
2 Hrs
20 Hrs
10 Hrs
2 Hrs
3 Hrs
21 Hrs
2 Hrs

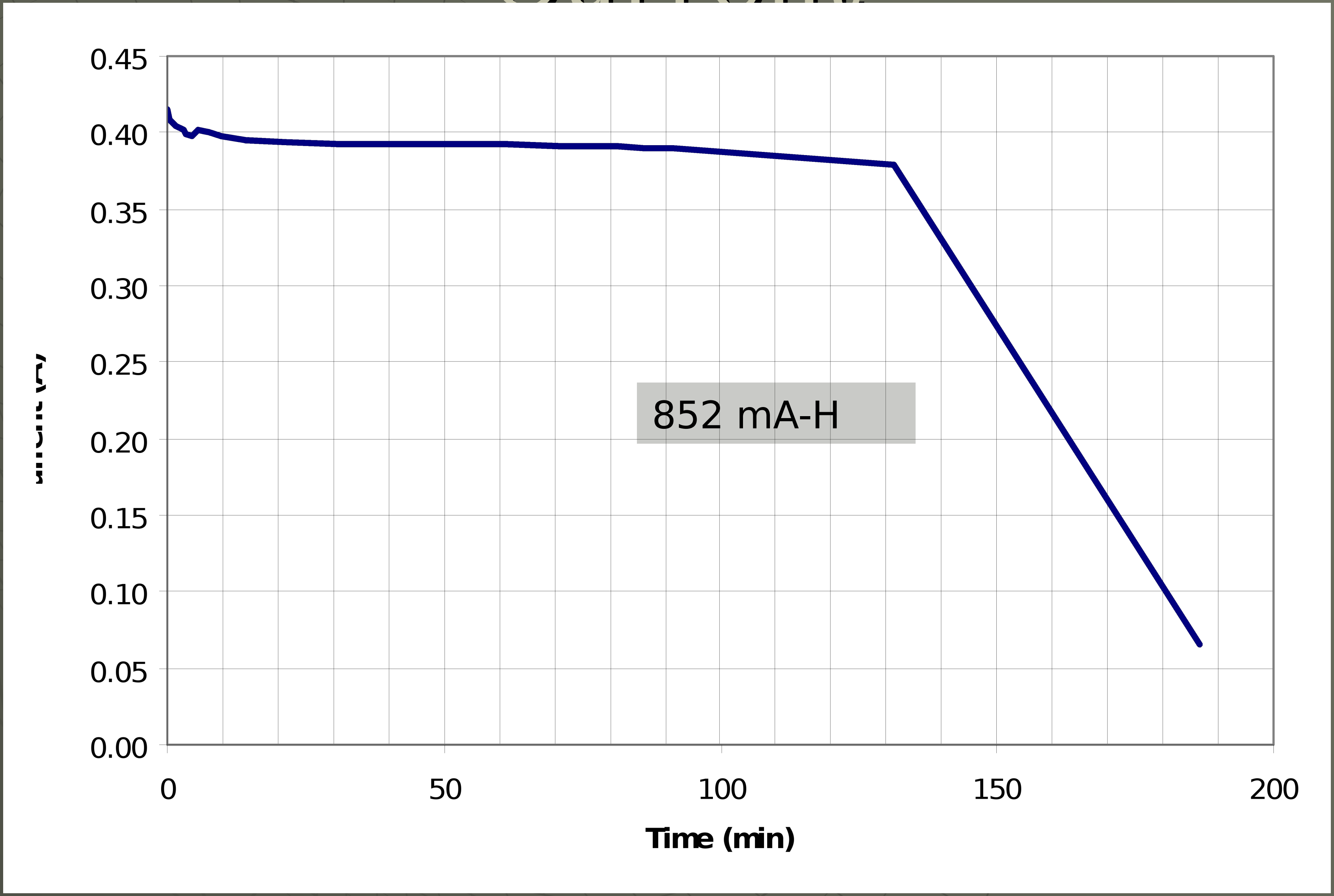
-60 °C Battery Test: Thermal Conditions



-60 °C Battery Test: Charge Temp

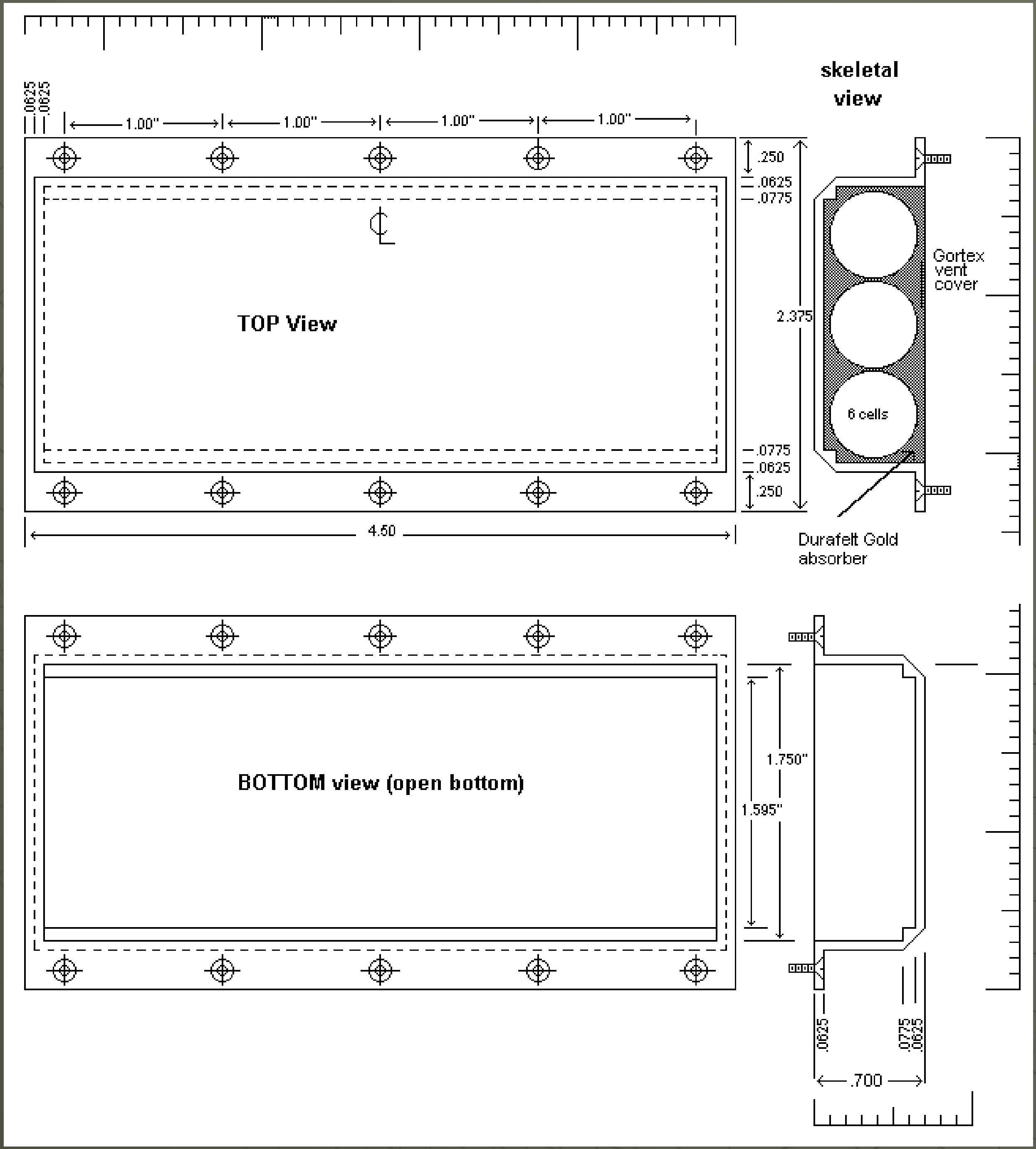


Post Cold Test Discharge Current



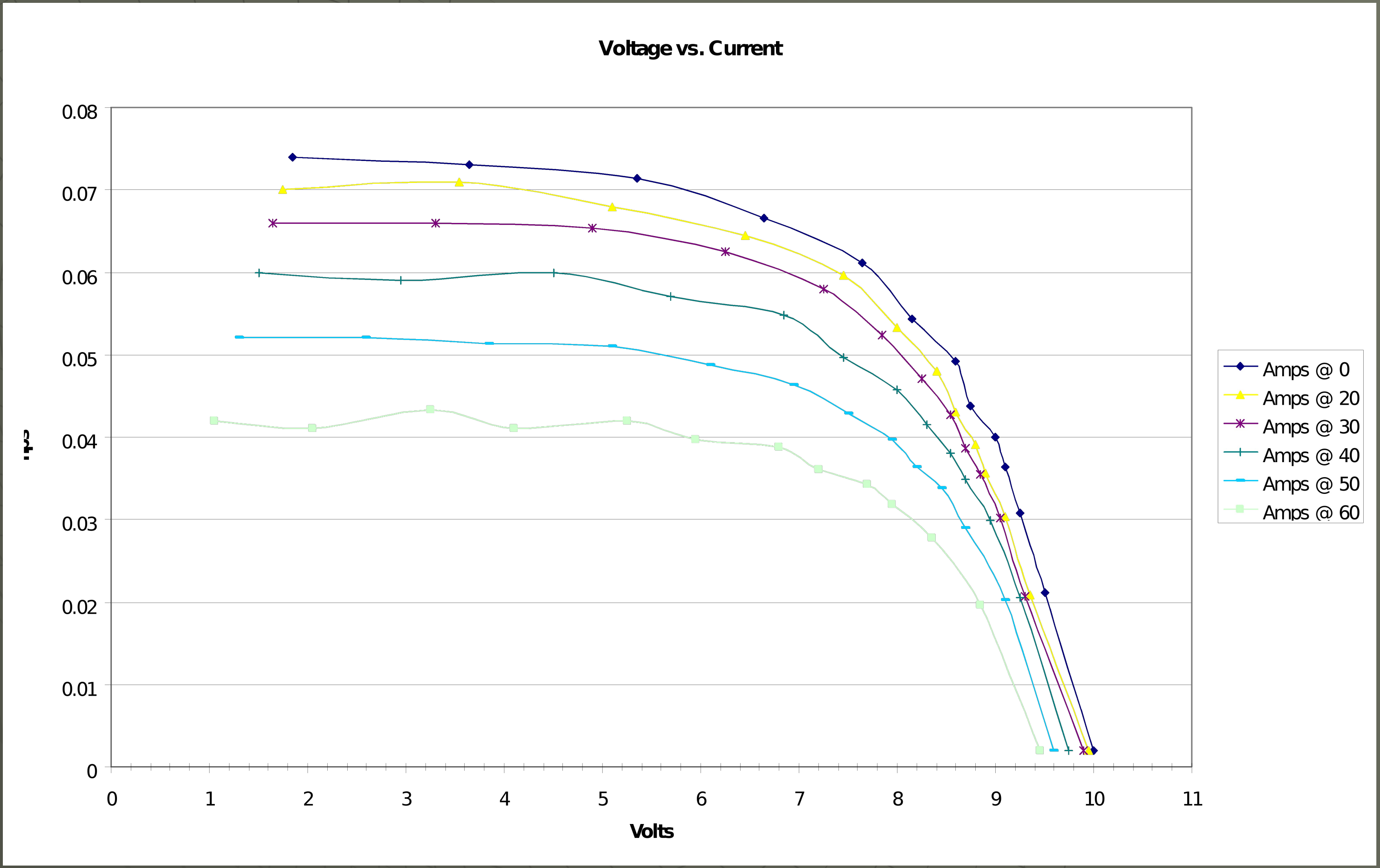
Post Cold Test Battery Condition
(No Leakage)

Battery Box

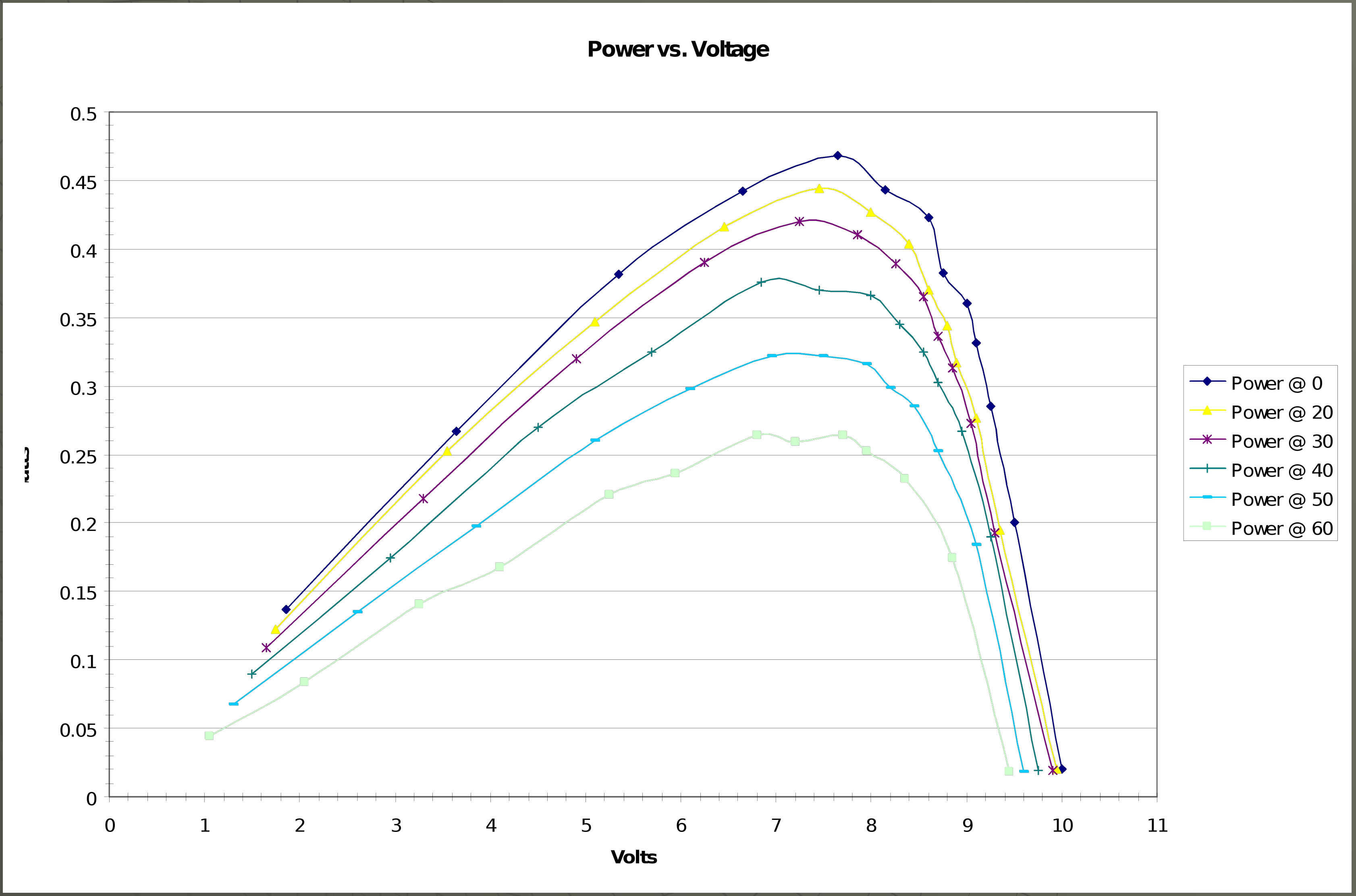


skeletal view
.0625
.0625
1.00"
1.00"
1.00"
1.00"
.250
.0625
.0775
2.375
Gortex vent cover
TOP View
6 cells
.0775
.0625
.250
4.50
Durafelt Gold absorber
BOTTOM view (open bottom)
1.750"
1.595"
.0625
.0775
.0625
.700

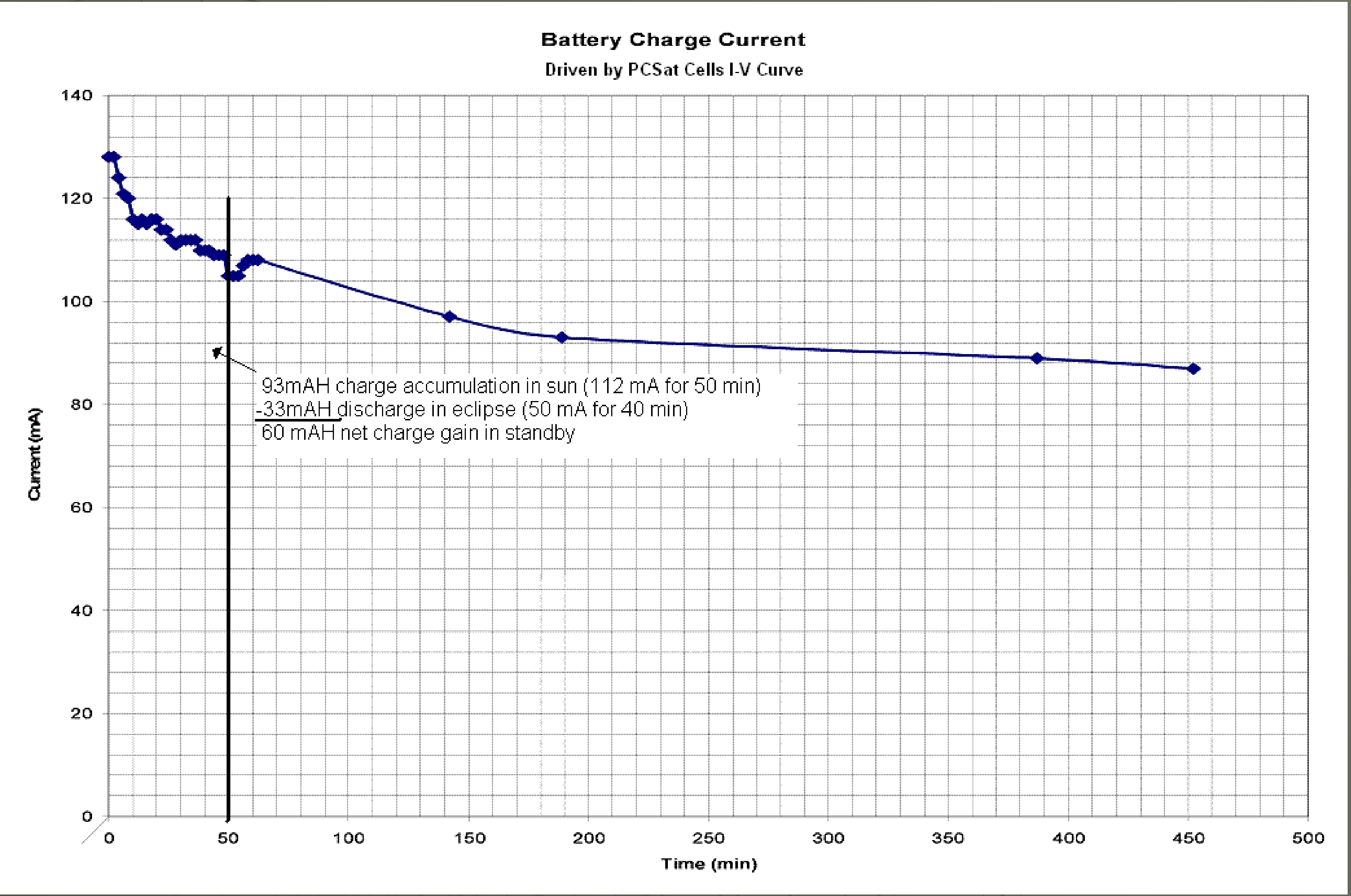
PCsat I-V Curve



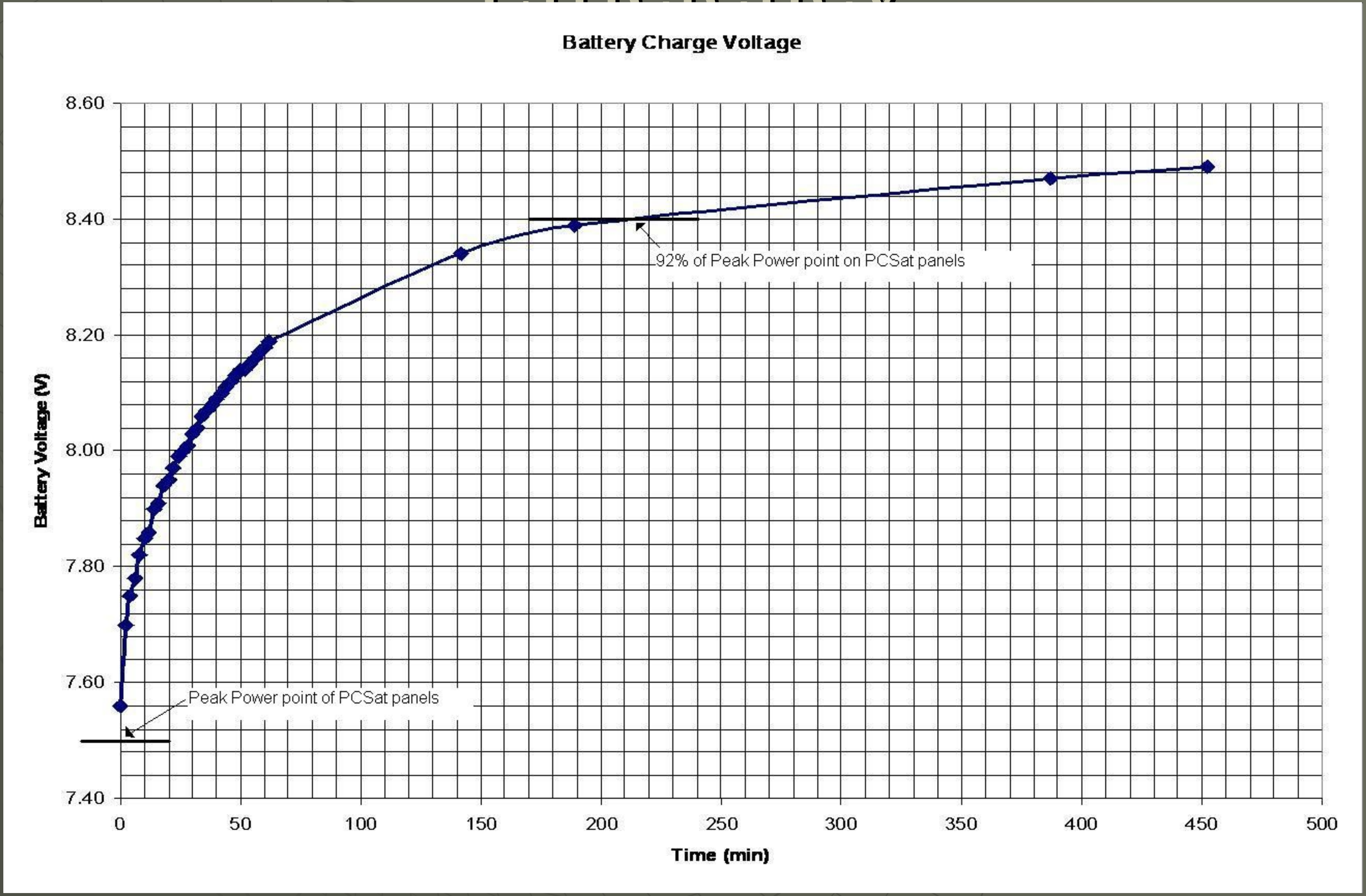
PCsat P-V Curve



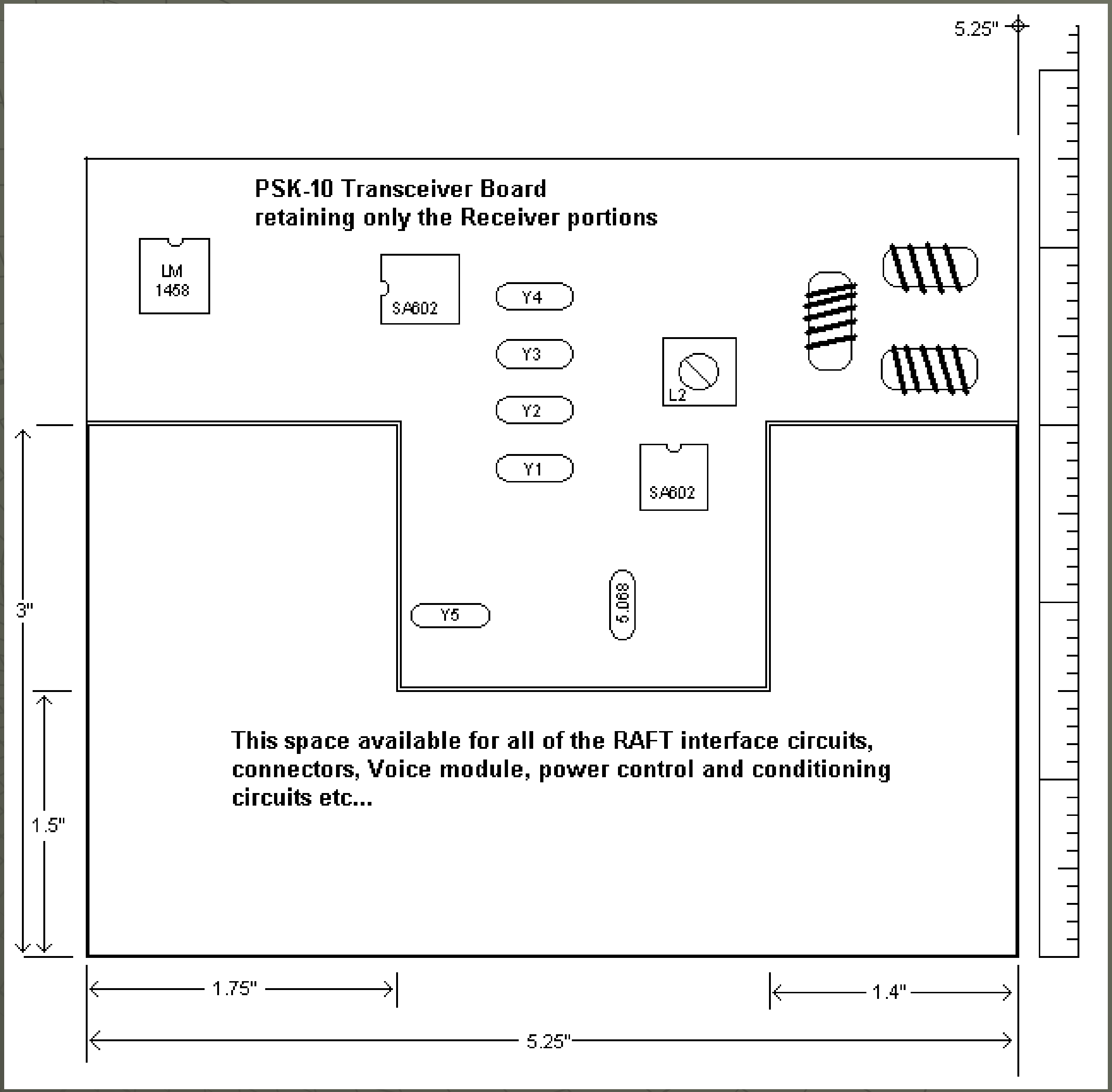
Dead Battery Recovery Test



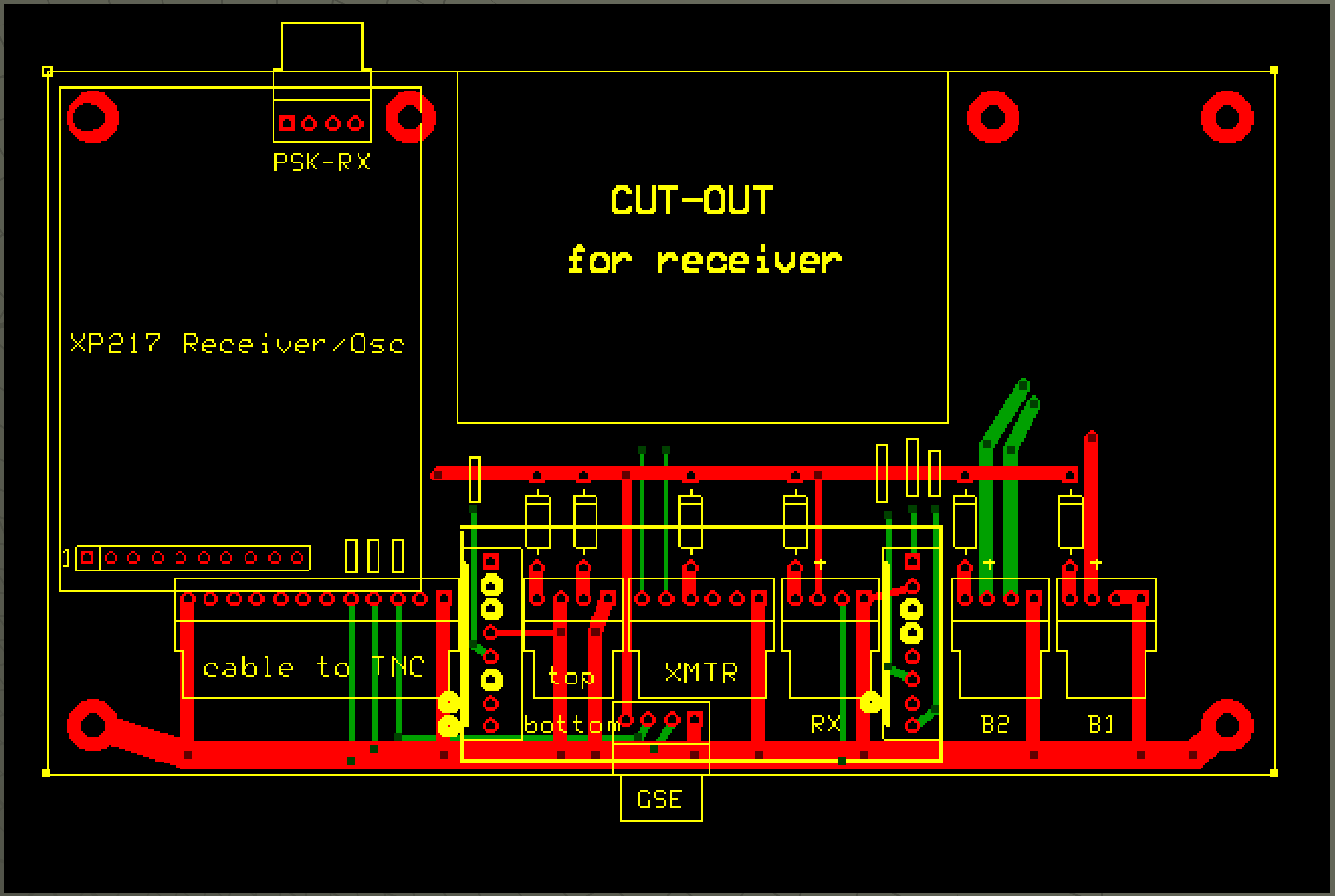
Dead Battery Charge Efficiency



Interface Board

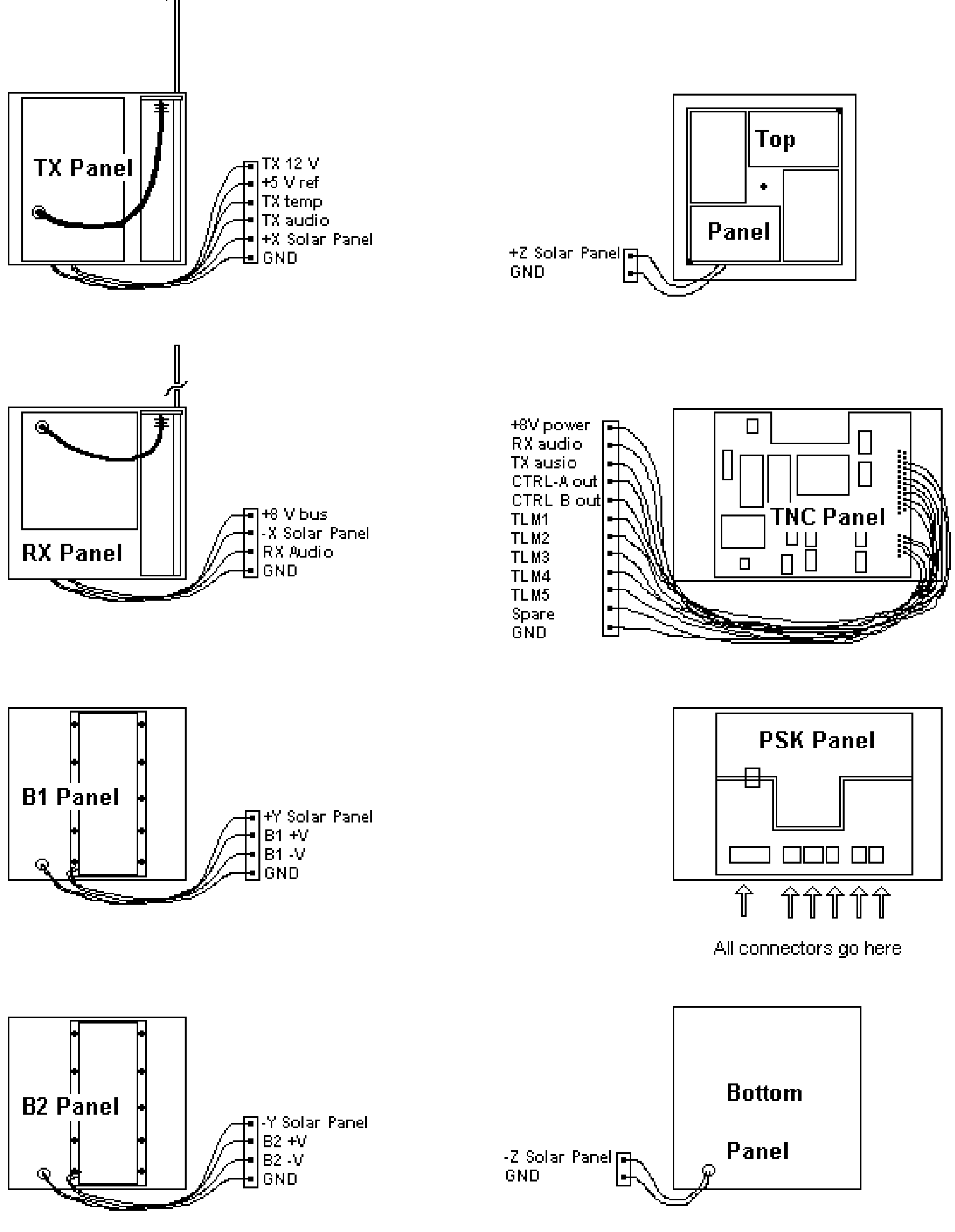


PCB Layout

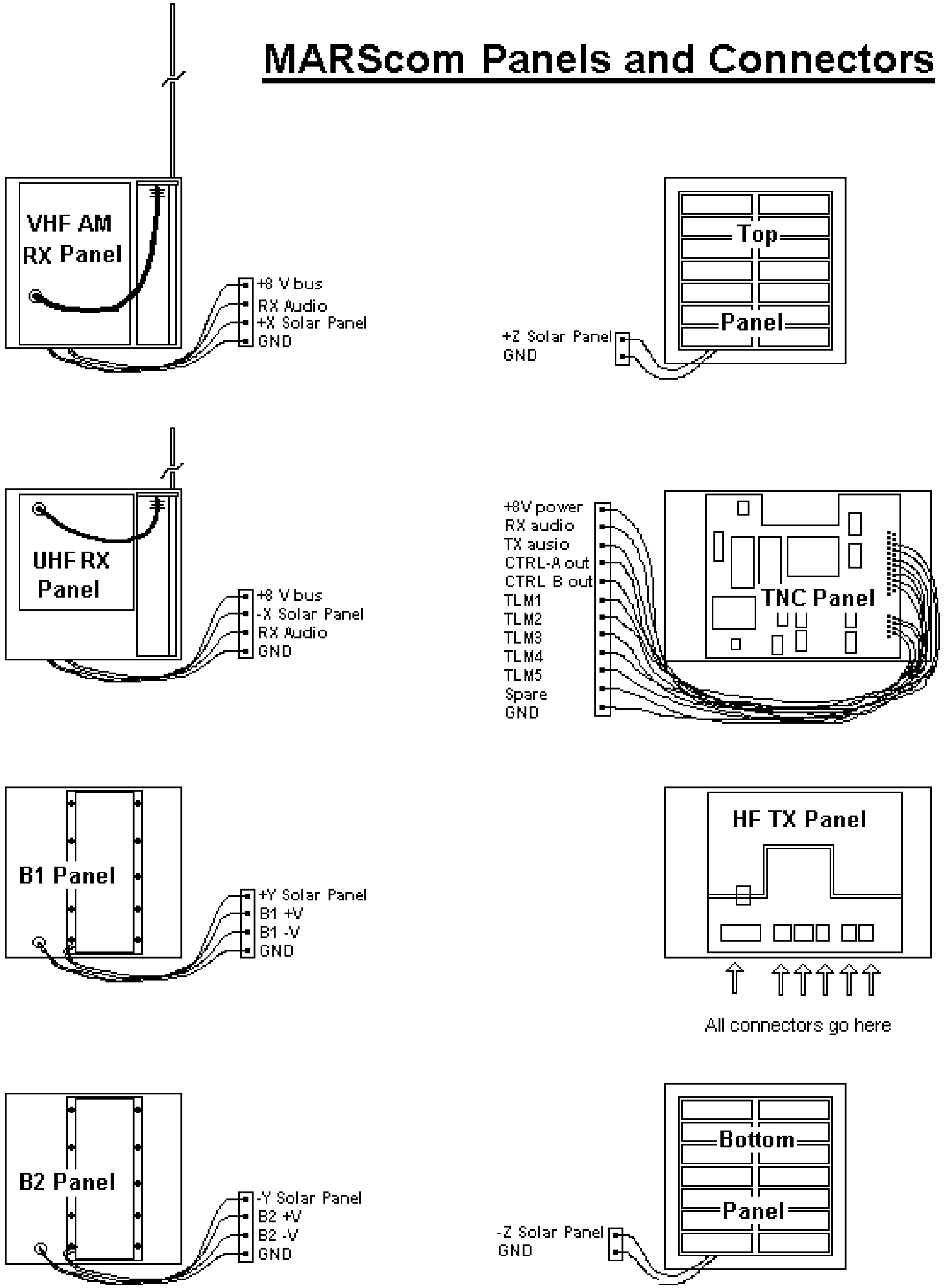


PSK-RX
CUT-OUT
for receiver
XP217 Receiver/Osc
cable to TNC
top
bottom
XMTR
RX
B2
B1
GSE

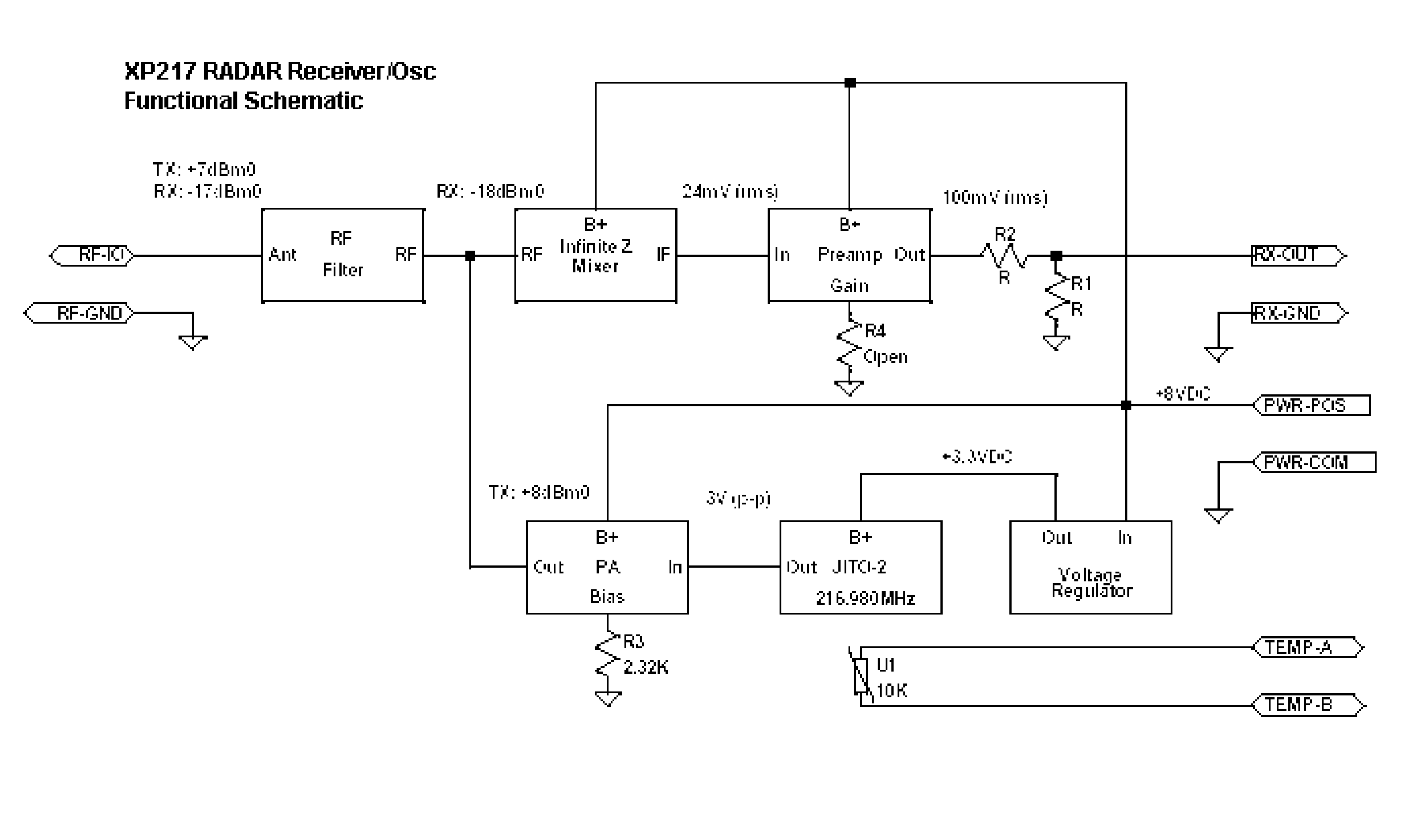
RAFT Panels and Connectors



MARScom Panels and Connectors



217Mhz Receiver

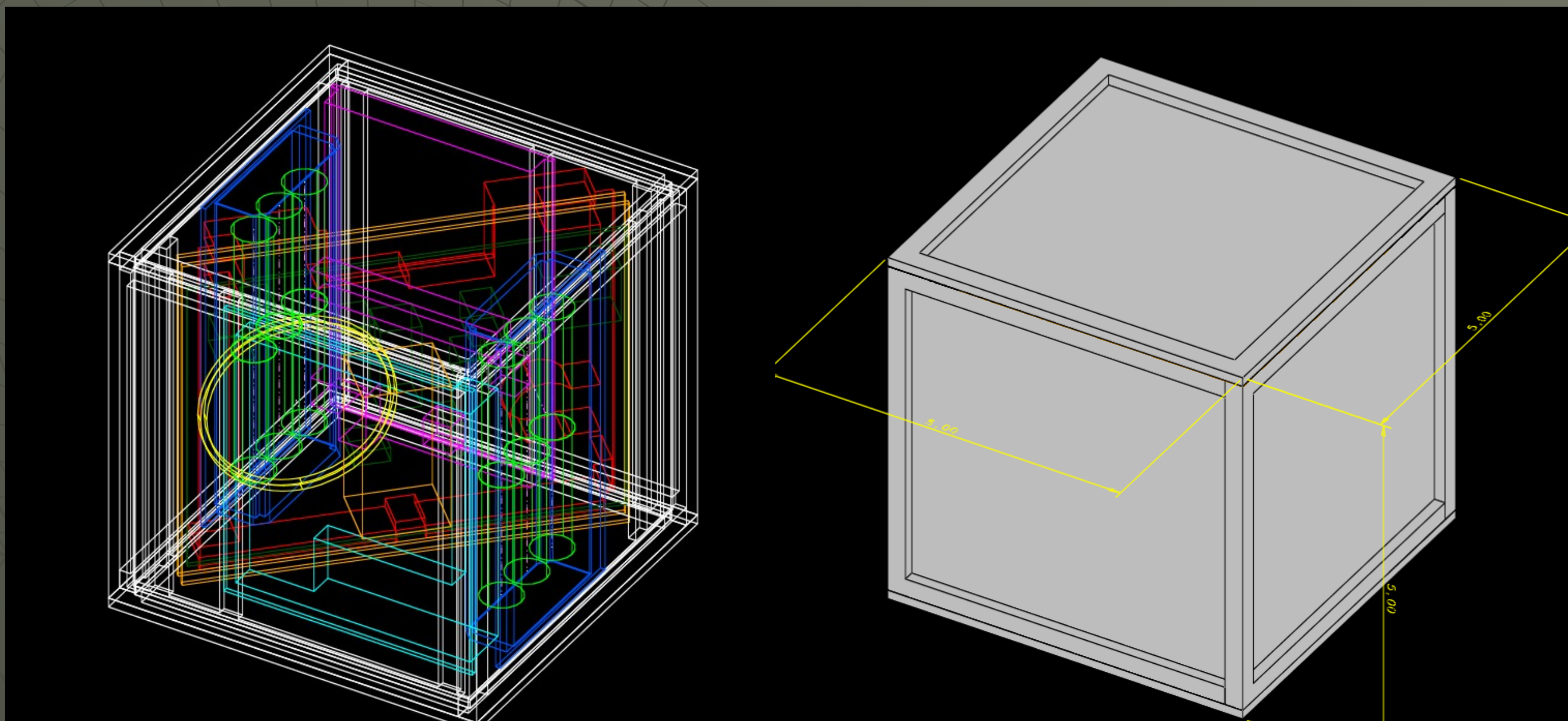


217Mhz Receiver PCB

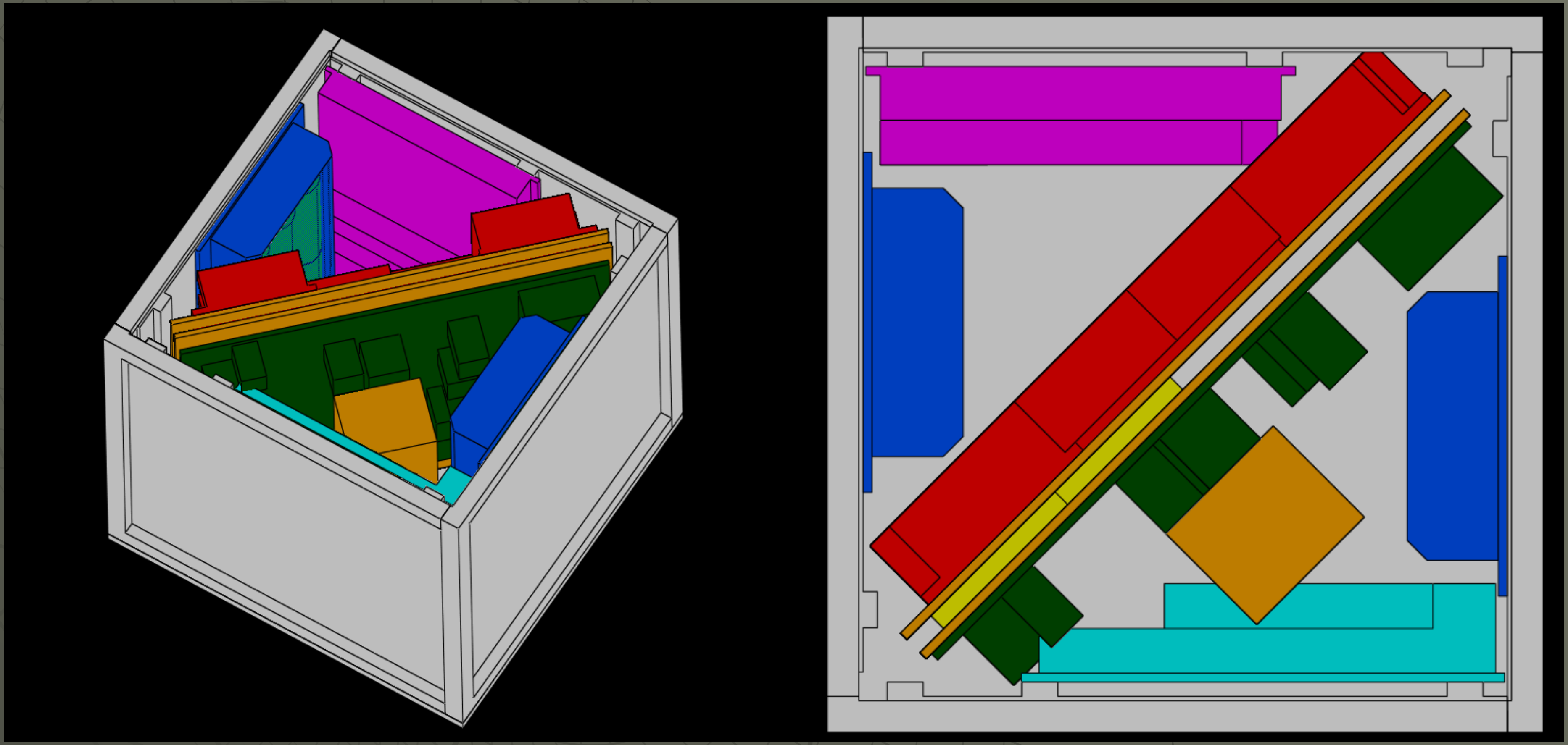
1.55in

2.175in

IDEAS Model



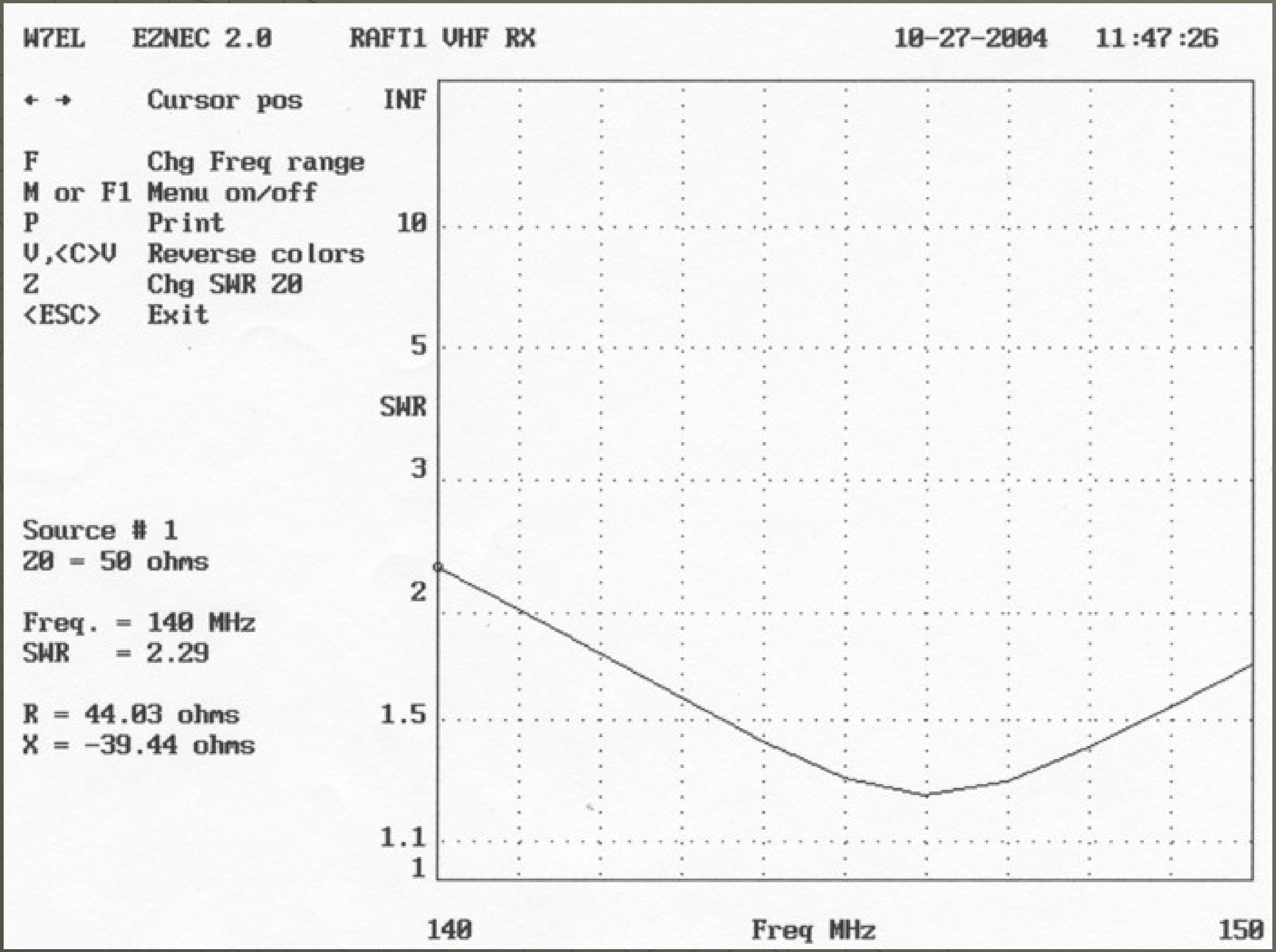
IDEAS Model



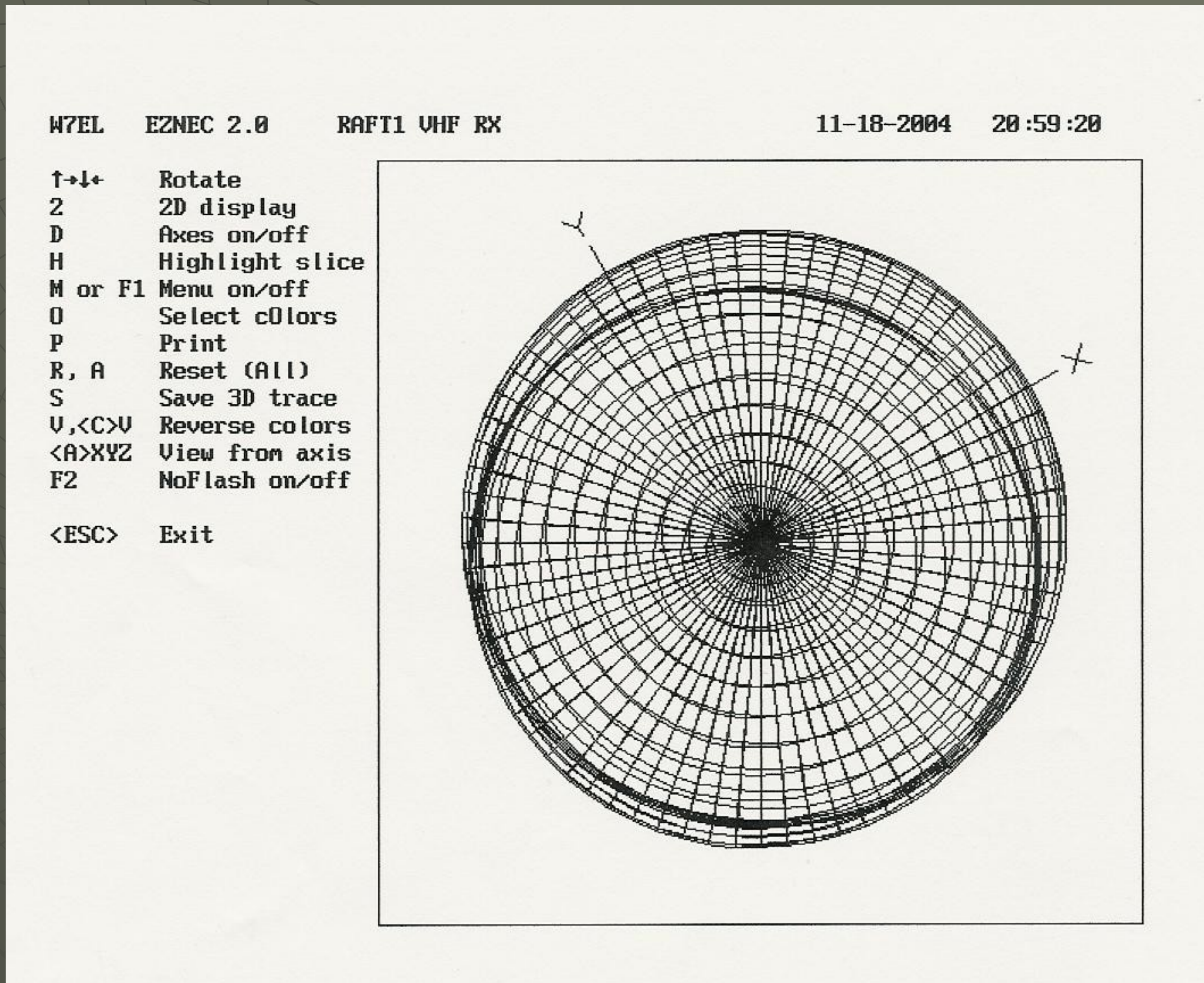
Communication

- RAFT1 requires an IARU Request Form
  - TX: 145.825 MHz, 2 Watt, 20 KHz B/W FM
  - RX: 29.400-29.403 MHz PSK-31 Receiver
  - RX: 145.825 MHz AX.25 FM
  - 216.98 MHz NSSS transponder
- MARScom requires a DD 1494
  - 148.375-148.975 MHz VHF cmd/user uplink
  - 24-29 MHz Downlink
  - 300 MHz UHF YP Craft Uplink Whip
    - Resonate at 216.98 MHz

VHF EZNEC Plot

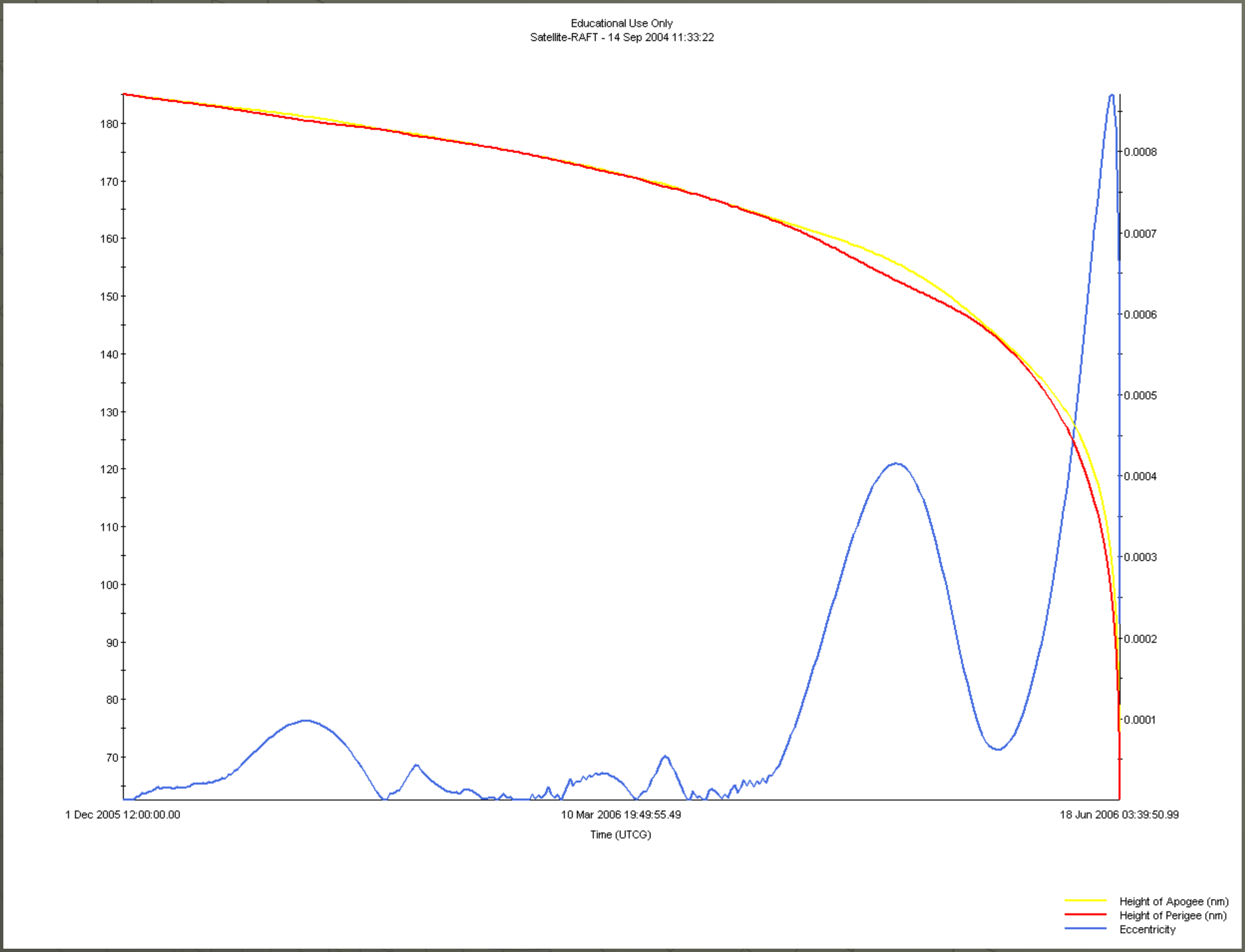


VHF EZNEC Plot

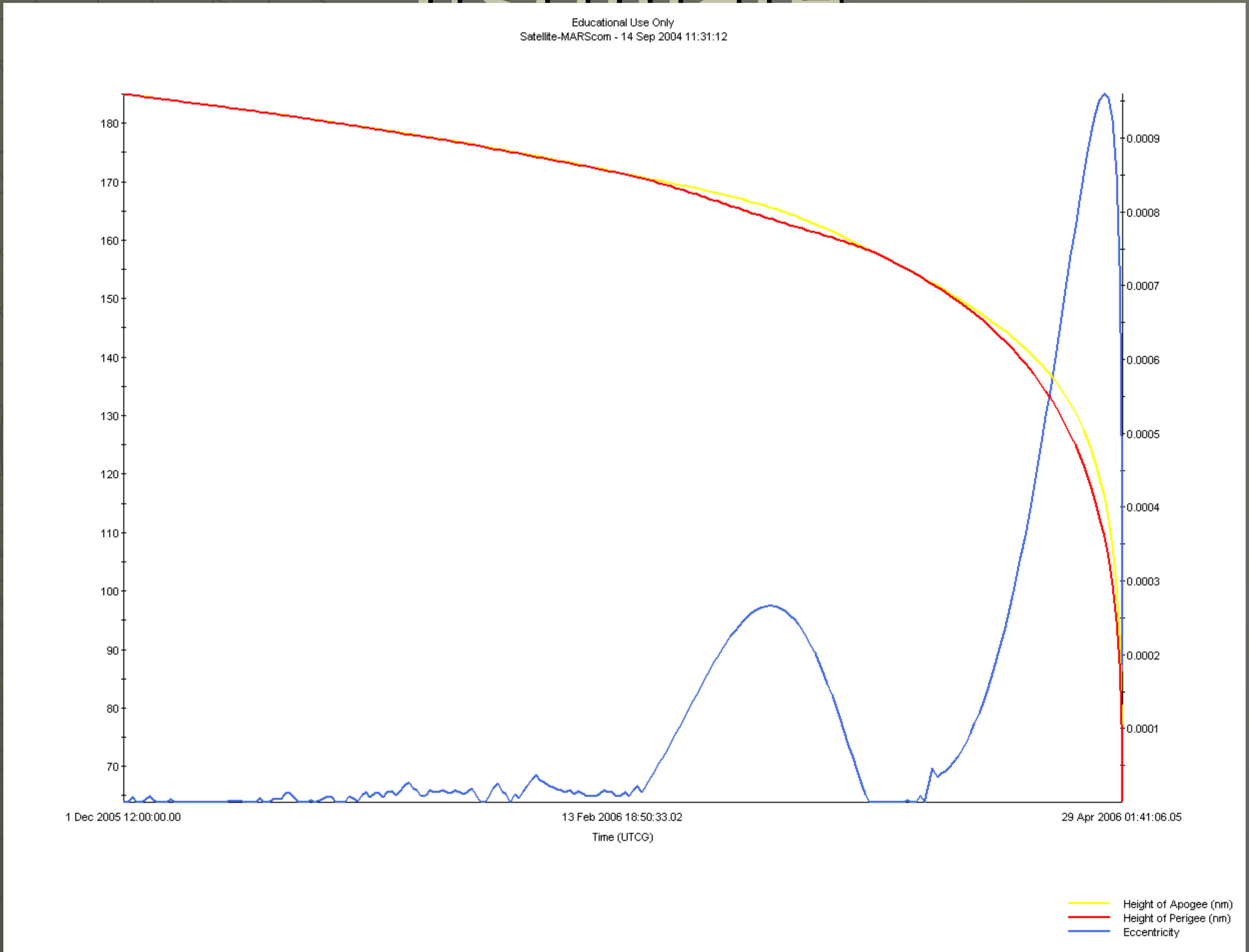


RAFT1 Magnetic Attitude Control

RAFT Lifetime Estimate



MARScom Lifetime Estimate



Mass Budget (kg)

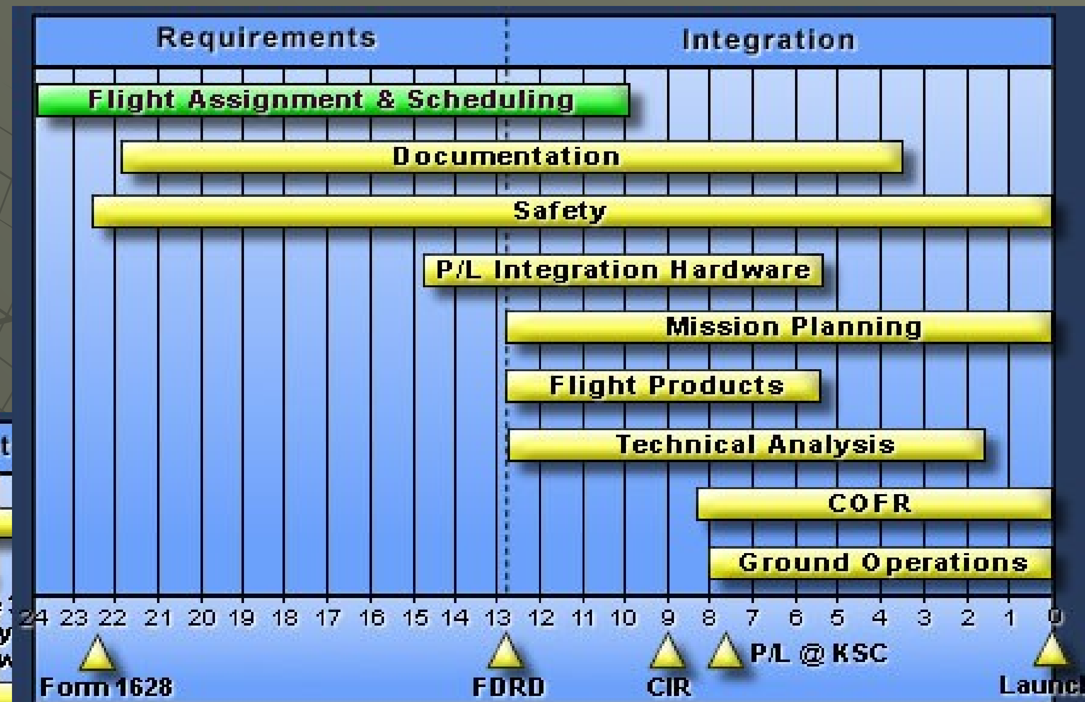
RAFT1

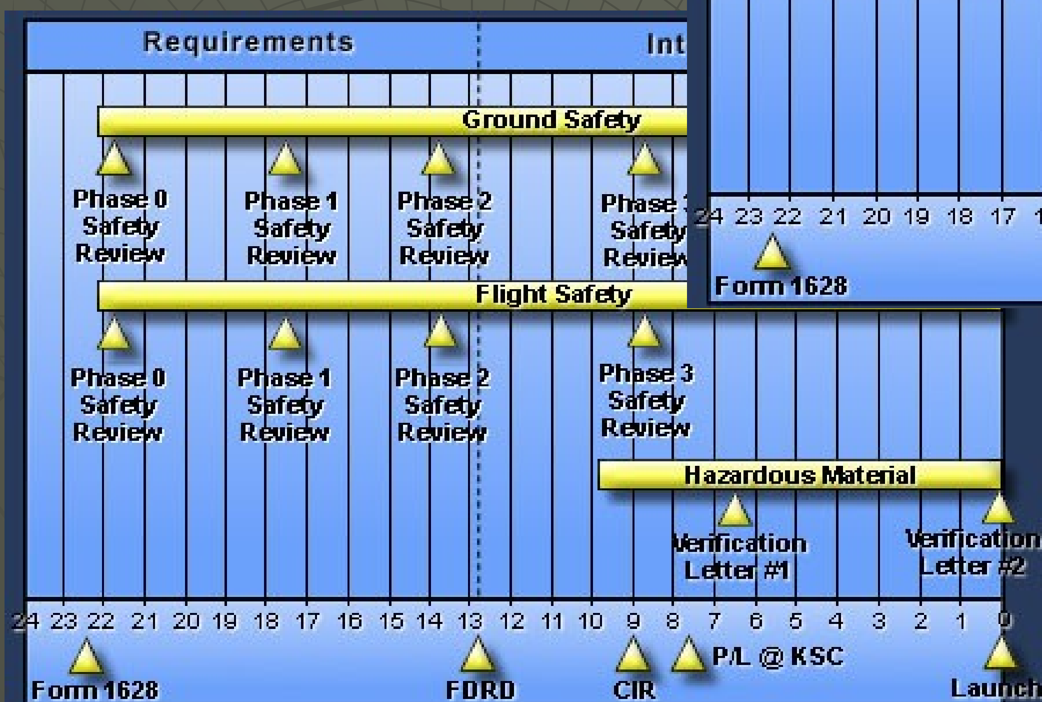
Component	Mass (kg)	Comments
Spool w/ HF Antenna	0.0536	Estimate
VHF Antenna	0.0046	Estimate
UHF Antenna	0.0046	Estimate
PSK-10 Board	0.1215	Includes Interface
TNC Board	0.1409	Actual
Interface Board	0	Estimated in PSK-10
Transmitter Board	0.0941	Actual
Receiver Board	0.083	Actual
Battery Boxes (2)	0.0406	Actual
AA Batteries (11)	0.2607	Actual
B1 Panel	0.138	Estimate
B2 Panel	0.138	Estimate
Transmitter Panel	0.138	Estimate
Receiver Panel	0.138	Estimate
Bottom Panel	0.138	Estimate
Top Panel	0.138	Estimate
PCSat Solar Panels (5)	0.3255	Actual
TOTAL	**1.9571**	
Max Allowed	**4**	

MARScom

Component	Mass (kg)	Comments
VHF FM RCVR	0.094	Estimate
VHF AM RCVR	0.094	Estimate
SSB Exciter	0.1	Estimate
1W Linear PA	0.04	Estimate
Splitter	0.04	Estimate
Decoder	0.04	Estimate
Batteries	0.168	Estimate
Ant/Spring combo	0.3	Estimate
20% Reserve	0.1752	Estimate
1/4" Aluminum	1.5	Estimate
Total	**2.5512**	
Max Allowed	**3**	

RAFT Integration & Safety





We will be using the “normal” processes as best we can

RAFT Schedule

ID	Task Name	Duration	Start	Finish	Predecessors
10	CDR	123 days?	Mon 8/30/04	Tue 2/15/05	
11	**Safety 1**	**67 days?**	**Mon 8/30/0**	**Tue 11/30/04**	
12	USMA Safety Pkg	24 days	Mon 8/30/04	Thu 9/30/04	
13	STP Safety Pkg	11 days?	Fri 10/1/04	Fri 10/15/0	12
14	Safety Submission	31 days?	Mon 10/18/0	Mon 11/29/0	13
15	Safety Review	1 day?	Tue 11/30/04	Tue 11/30/0	14
16	Safety 2	123 days?	Mon 8/30/04	Tue 2/15/05	
17	Safety 3	209 days?	Mon 8/30/04	Wed 6/15/05	
18	**Mission**	**22 days?**	**Mon 8/30/04**	**Tue 9/28/04**	
19	Orbit Decay	3 days?	Mon 8/30/04	Wed 9/1/04	
20	Frequency Allocation	22 days?	Mon 8/30/04	Tue 9/28/04	
21	**Separation and Antenna**	**50 days?**	**Mon 8/30/04**	**Fri 11/5/04**	
22	**Physics**	**13 days?**	**Mon 8/30/0**	**Wed 9/15/04**	
23	Computations	10 days?	Mon 8/30/04	Fri 9/10/04	
24	Air Table	13 days?	Mon 8/30/04	Wed 9/15/04	
25	**Mechanical**	**50 days?**	**Mon 8/30/04**	**Fri 11/5/04**	
26	Mass Models	6 days?	Wed 9/1/04	Wed 9/8/04	
27	Antenna Springs	50 days?	Mon 8/30/04	Fri 11/5/04	
28	**Matching**	**8 days?**	**Mon 8/30/04**	**Wed 9/8/04**	
29	EZ NEC Model	8 days?	Mon 8/30/04	Wed 9/8/04	
30	**EPS**	**116 days?**	**Mon 8/30/04**	**Sun 2/6/05**	
31	**Solar**	**116 days?**	**Mon 8/30/04**	**Sun 2/6/05**	
32	Design/ ID cell	70 days?	Mon 8/30/04	Fri 12/3/04	
33	Procure	22 days?	Fri 1/7/05	Sun 2/6/05	
34	**Batteries**	**55 days?**	**Wed 9/15/0**	**Tue 11/30/04**	
35	Thermal Analysis	23 days?	Wed 9/15/04	Fri 10/15/04	
36	Cell Selection	33 days?	Fri 10/15/04	Tue 11/30/04	
37	Regulator	1 day?	Mon 8/30/04	Mon 8/30/04	
38	Power Budget	7 days?	Mon 8/30/04	Tue 9/7/04	

Shuttle Safety Requirements

- Fracture Control Plan
- Fastener integrity
- A structural model of RAFT
- Venting analysis
- Simple mechanisms
- Materials compatibility / Outgassing
- Conformally coated PC boards
- Wire sizing and fusing
- Radiation hazard
- Battery safety requirements
- Shock and vibration

Battery Safety Requirements

- Must have circuit interrupters in ground leg
- Inner surface and terminals coated with insulating materials
- Physically constrained from movement and allowed to vent
- Absorbent materials used to fill void spaces
- Battery storage temperature limits are -30°C to +50°C
- Prevent short circuits and operate below MFR’s max
- Thermal analysis under load and no-load
- Battery must meet vibration and shock resistance stds
- Must survive single failure without inducing hazards
- Match cells for voltage, capacity, and charge retention

Key Requirement Documents

- Key Requirement Documents:
  - NSTS 1700.7B, Safety Policy and Requirements for Payloads Using the Space Transportation System
  - NSTS/ISS 18798, Interpretations of NSTS Payload Safety Requirements
  - NSTS/ISS 13830C, Payload Safety Review and Data Submittal Requirements
  - KHB 1700.7B, Space Shuttle Payload Ground Safety Handbook
  - NSTS 14046, Payload Verification Requirements
  - NASA-STD-5003, Fracture Control Requirements for Payloads using the Space Shuttle

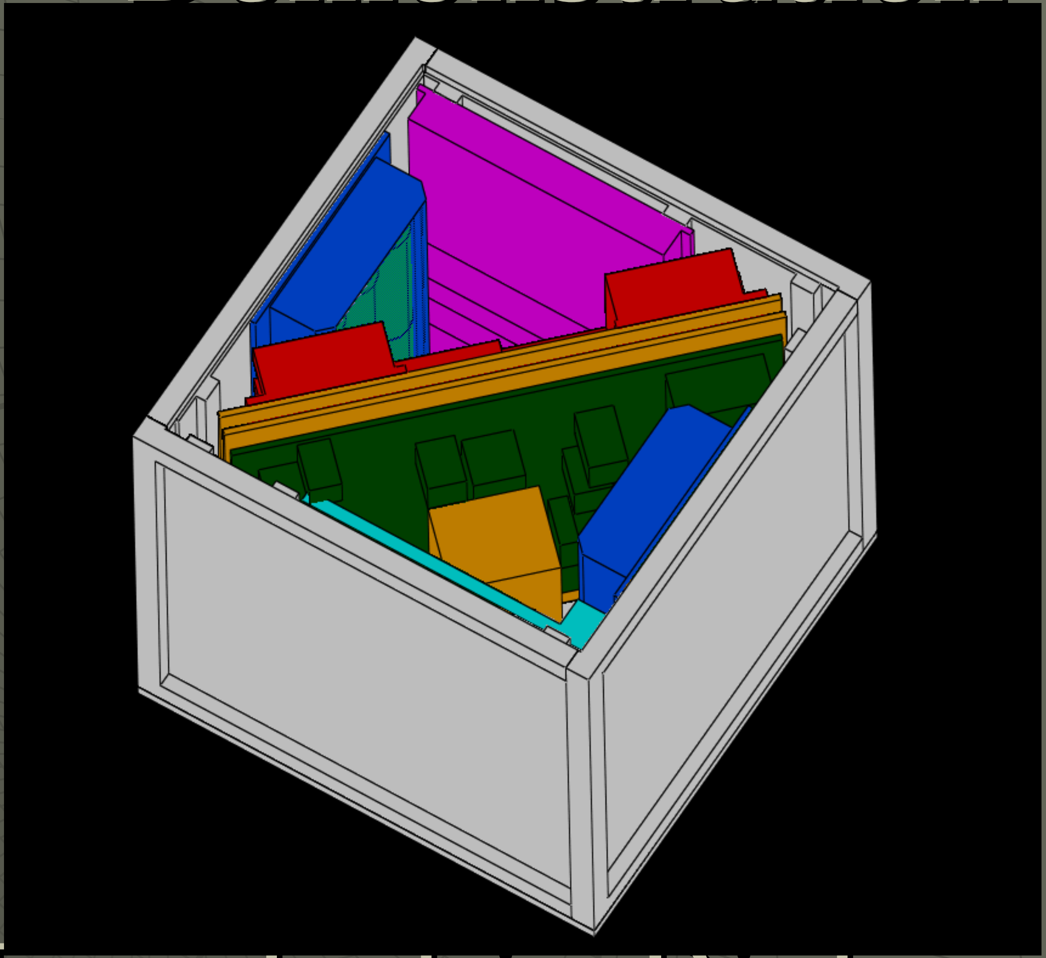
Key Reference Documents

- Reference/Requirements Documents (not all inclusive):
  - JSC 26943, Guidelines for the Preparation of Payload Flight Safety Data Packages and Hazard Reports
  - MSFC-STD-3029, Guidelines for the Selection of Metallic Materials for SCC Resistance
  - MSFC-HDBK-527/JSC 09604 (MAPTIS), Materials Selection List for Space Hardware Systems
  - JSC 20793, Manned Space Vehicle Battery Safety Handbook
  - TM 102179, Selection of Wires and Circuit Protective Devices for STS Orbiter Vehicle Payload Electrical Circuits

RAFT Schedule

- Systems Definition complete – 15 APR 2004
- Systems Requirement Baseline – 15 SEP 2004 (SRR)
- Prelim.Design Review– 19 NOV 2004
- Engineering Model Available– 15 JAN 2004
- System Design Complete – 15 FEB 2005 (CDR)
- Flight unit for Environmental testing – May 2005
- Flight Hardware for Integration/Flight – OCT 2005
- Launch – FEB 2005

IDEAS Model Demonstration



Located in Rickover Computer Labs